QH541.5
.M3
F88
1993

United States
Department of
Agriculture

Forest
Service

**Southwestern
Region**

# Management of Wetlands at High Altitudes in the Southwest

**Acknowledgments**

Bill Zeedyk, US Forest Service retired, provided the key stimulus for this handbook. Bill's strong interest in effective management coupled with the initiative established by the North American Waterfowl Management Plan identified the need to better understand and manage montane habitats on Forest Service Lands in Arizona and New Mexico. Discussions with several individuals helped to focus the content of this handbook, most noteworthy are Bill Zeedyk, Dave Patton, Jim Gammonley, Jim Ringelman, Mickey Heitmeyer, Fritz Reid, Greg Goodwin, Mehl Wilhelm, and Bob Vahle. In addition this group kindly reviewed the manuscript. Sandy Clark provided critical editorial assistance. The University of California Press kindly provided permission to reproduce plant illustrations.

USDA policy prohibits discrimination based on race, color, national origin, sex, age, religion, or disability. Any person who believes he or she has been discriminated against in any USDA-related activity should immediately contact the Secretary of Agriculture, Washington, DC 20250.

Printed on recycled stock • 10/93

United States
Department of
Agriculture

Forest
Service

**Southwestern
Region**

# Management of Wetlands at High Altitudes in the Southwest

L. H. Fredrickson and B. D. Dugger
The School of Natural Resources
Gaylord Memorial Laboratory
University of Missouri

RMRS Library
USDA Forest Service

MAY 2 2 2006

240 W Prospect Rd
Fort Collins CO 80526

United States
Department of
Agriculture

Forest
Service

**Southwestern
Region**

# Management of Wetlands at High Altitudes in the Southwest

L. H. Fredrickson and B. D. Dugger
The School of Natural Resources
Gaylord Memorial Laboratory
University of Missouri

RMRS Library
USDA Forest Service

MAY 2 2 2006

240 W Prospect Rd
Fort Collins CO 80526

# Contents


Introduction . . . . . 1

Background . . . . . 3
- Climate . . . . . 3
- Wetland Formation . . . . . 4
- Wetland Classification . . . . . 4
- Current Use and Management . . . . . 5

Wetland Ecology . . . . . 7
- Wetland Model . . . . . 7
- Macroinvertebrtates . . . . . 8
- Wetland Structure . . . . . 11
- Wetland Function . . . . . 12
- Wetland Complexes . . . . . 15

Wetland Wildlife . . . . . 17
- Waterfowl . . . . . 17
- Other Wetland Wildlife . . . . . 24

An Approach to Wetland Management . . . . . 27
- The Wetland Complex . . . . . 27
- Individual Basins . . . . . 28
- Management Considerations Within A Watershed . . . . . 29
- Management Within A Basin . . . . . 31
- Food Production . . . . . 34

Suggested Readings . . . . . 39

Selected Literature . . . . . 41

Appendix
- List of Common and Scientific Names of Animals Appearing in the Text, Tables and Figures . . . . . 45
- List of Common and Scientific Names of Plants Appearing in the Text . . . . . 46
- Common Plants of Montane Wetlands in Arizona . . . . . 47
- Common Birds of Montane Wetlands in Arizona . . . . . 55
- Common Invertebrates of Montane Wetlands in Arizona . . . . . 64

# Introduction

North American migratory waterbirds have life history strategies that rely on many wetland types, extending from the tropics to the arctics. Among the waterbirds, waterfowl are one well known group specifically adapted to wetland ecosystems. The dynamic nature of wetland habitats, whose abundance and distribution can vary largely because of annual and seasonal fluctuations in precipitation, influenced the abundance and distribution of waterfowl in North America. The high mobility of waterfowl allowed them to exploit wetland habitats across the continent thus mitigating the effects of regional droughts and allowing them to maintain high population levels.

European settlement of North America has greatly changed the continental wetland environment. Within the lower 48 states, every wetland has probably been impacted by man in some way. Agriculture, urban and industrial development, and forestry practices have destroyed or severely modified 70% of the continent's wetlands. Many of the remaining wetlands have been greatly altered from their pristine state. In the southwest, waterfowl historically congregated in large numbers during non-breeding months on wetlands associated with the Colorado and other rivers in Arizona. Their importance in particular to northern pintail, cinnamon teal, and snow goose populations is well documented. The destruction or modification of these wetlands by dams and channelization along with lower water tables, has reduced the number and changed the distribution of winter and migrating waterfowl in the state. These losses place added importance on remaining wetlands.

In the southwestern United States, riverine wetland losses have placed added importance on montane wetland basin complexes to support regional waterfowl populations. In Arizona these occur above 6,400 feet and are located north of the Mogollon Rim, on the Colorado Plateau. Montane wetlands in Arizona and New Mexico provide breeding habitat for several species of waterfowl, particularly cinnamon teal, pintail, mallard, ruddy duck, and redhead as well as habitats for many other species during migration. Total waterfowl production on these systems is of minor importance to the size of continental waterfowl populations, however other factors make these areas worth protecting and managing.

These wetlands constitute the southern most breeding range for many temperate nesting waterfowl. Their importance as a source of genotypic variation for continental populations is unknown. Historically, these wetlands have been more valuable to waterbirds as spring and fall migration areas. In addition, band recovery data indicate that birds produced on these wetlands mostly winter in southern Arizona and New Mexico, providing additional recreational opportunities for hunters and birders within these states. Finally, these areas also support breeding populations of other non-game wetland species as well as influencing terrestrial animal life. Thus, montane wetlands are an important factor influencing biotic diversity in the region, not only influencing the number of species present but their density and distribution as well.

A decline in waterfowl populations coupled with changing public attitudes about wetland protection and increased public use of these wetlands has increased the interest in understanding, managing, and protecting montane wetlands. This handbook was developed as a result of this new interest. Its purpose is to: 1) provide background knowledge about wetlands function; 2) give a brief overview of the plant and animal species that rely on these wetlands for their existence and the strategies they use to exploit wetland habitats; 3) review potential management options for enhancing wetland productivity and use, particularly by waterfowl; and 4) create guidelines that can be used for evaluating the potential/need for management on a wetland.

# Background

Montane wetlands are important to a diverse group of wetland and terrestrial animals. A complete discussion of all these interactions among plants and animals is beyond the scope of this document. Instead we focus on how wetland processes and management impact use by waterfowl species. However, successful management plans that seek to meet the needs of all the waterfowl species using a wetland complex will also provide resources for the host of other species using montane wetlands.

The geographic region covered by this handbook includes the White Mountain, San Francisco Plateau, and to a lesser extent Northern waterfowl regions in Arizona and similar habitats in New Mexico (Fig. 1). Most wetlands in these regions occur between 6,600 and 8,900 feet in the Transition, Canadian, and Hudsonian Elevational Life Zones. In the White Mountains, the wettest part of Arizona, wetlands occur predominately between 6,900 - 9,200 feet, and account for 70% of all waterfowl production in Arizona. Wetlands on the San Francisco Plateau, located between 6,600 and 7,250 feet, account for the balance of waterfowl production in the state. New Mexico has fewer montane wetlands than Arizona, these are primarily located in the Chuska Mountain region in the northwest and areas adjacent to the White Mountains in Arizona.

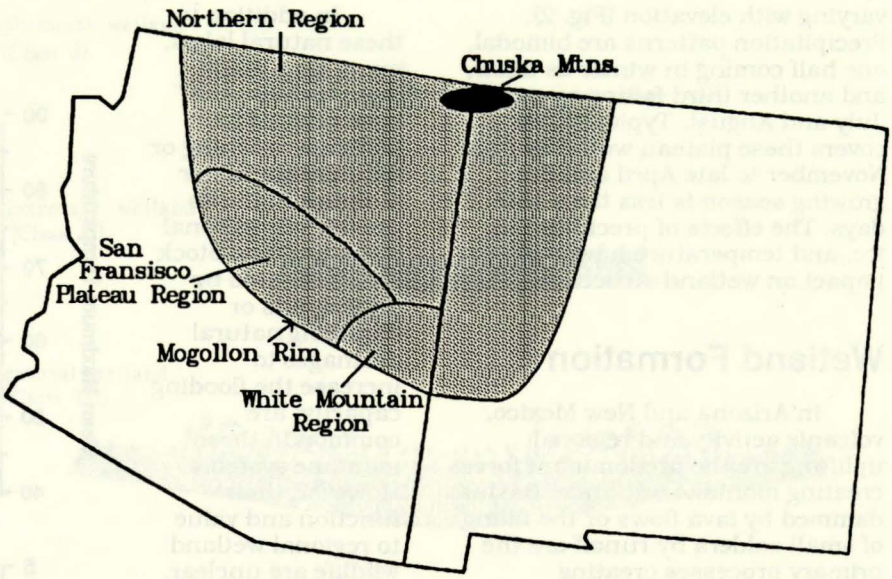



**Figure 1.** Geographic area covered (shaded) showing the three Arizona waterfowl regions discussed by Brown (1985).

The five national forests that occur all or partly in the area covered, contain almost 19,600 acres of lacustrine and palustrine wetlands (Table 1). These wetlands range in permanence, with some holding water for periods as short as a month, while others are essentially permanently flooded except during dry years. A large component of these more permanently flooded wetlands are livestock tanks and seasonal wetlands that have been enlarged for recreational purposes.

## Climate

The climate of this region is characterized by mild summers and cold winters, with daily temperatures and precipitation

**Table 1. National forests containing montane wetlands in Arizona and New Mexico.**

| National Forest | Wetland Acreage Palustrine (ac) | Palustrine (n) | Lakes (ac) | Lakes (n) | Reservoirs (ac) | Reservoirs (n) | Total (ac) | Total (n) |
|---|---|---|---|---|---|---|---|---|
| Apache-Sitgreaves | 1,112 | (24) | 125 | (2) | 4,085 | (32) | 5,222 | (58) |
| Coconino | 345 | (21) | 11,430 | (62) | 182 | (1) | 11,958 | (84) |
| Cibola | 14 | (1) | 243 | (4) | 29 | (1) | 286 | (6) |
| Gila | 25 | (2) | 568 | (7) | — | — | 593 | (9) |
| Kaibab | — | — | 509 | (14) | 46 | (1) | 555 | (15) |
| Total | 1,496 | (48) | 12,875 | (89) | 4,342 | (35) | 18,714 | (172) |

varying with elevation (Fig. 2). Precipitation patterns are bimodal, one half coming in winter as snow, and another third falling as rain in July and August. Typically, ice covers these plateau wetlands from November to late April and the growing season is less than 150 days. The effects of precipitation, ice, and temperature have a major impact on wetland structure.

## Wetland Formation

In Arizona and New Mexico, volcanic activity and regional uplifting are the predominant forces creating montane wetlands. Basins dammed by lava flows or the filling of small caldera by runoff are the primary processes creating semipermanent wetlands on Arizona's San Francisco Plateau. Wetlands also form in the shallow depressions of old lava flows. In the Chuska Mountains of northeastern Arizona and northwestern New Mexico, the tertiary sandstone deposits capping the mountains contains many small basins. Many of these natural wetlands are isolated basins that rely solely on precipitation as a source of water input but some are also fed by springs. The water table is below the level of the wetland basin. Water retention in these perched wetlands is facilitated either by soils high in clay or bedrock that greatly reduce seepage (Fig. 3).

In addition to these natural lakes, many man-made waterbodies have been created to facilitate ranching or for domestic water supplies that also provide recreational opportunities. Stock tanks, created by digging pits or damming natural drainages to increase the flooding capacity, are common in these montane systems. However, their function and value to regional wetland wildlife are unclear. Although reservoirs for irrigation or as a source of domestic water supplies are not classed as wetlands they often have some benefits for wetland wildlife.

## Wetland Classification

As a guideline, this handbook uses the classification system developed by Stewart and Kantrud (1971) for prairie pothole wetlands. This system classifies wetlands according to dominant plant associations occurring in the central part of a wetland. These plant communities are directly correlated with wetland flooding depth and duration.

Ephemeral (Class I), temporary (Class II), seasonal (Class III), and semipermanent (Class IV) wetland basins occur naturally in montane areas. Permanent (Class V) wetlands are mostly reservoirs created for agricultural or urban activities.

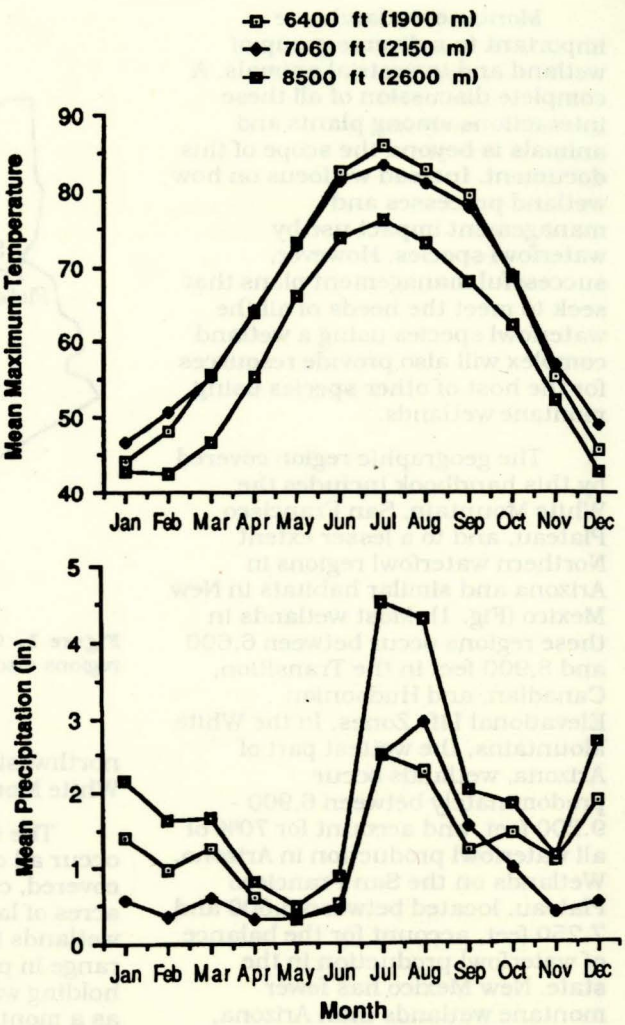



**Figure 2.** Mean monthly temperature and precipitation at different altitudes in the White Mountain Region of Arizona.

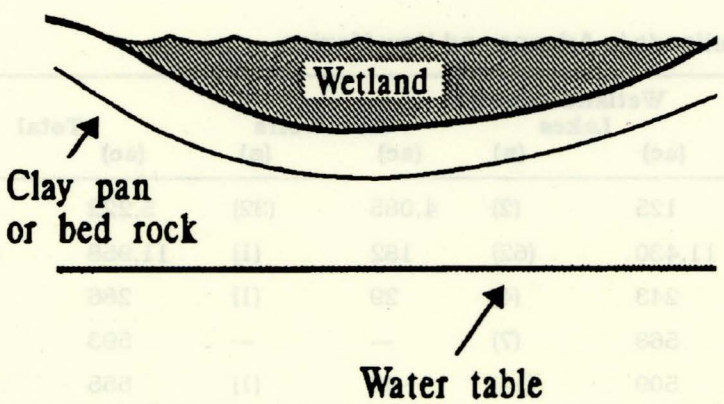



**Figure 3.** Relationship of montane wetland to water table. Bedrock or clay deposits greatly reduce seepage thus standing water accumulates.

Ephemeral wetlands have very short flooding periods, which usually precludes the growth of extensive emergent vegetation (Fig. 4). Temporary wetlands are characterized by shallow flooding for short periods, salt grass and manna grass are common dominant plant species in the deepest zone. Seasonal wetlands are flooded for several months in spring and early summer; common plants included spike rush and water plantain. Semipermanent wetlands support cattail, bulrush, and some submergents throughout the deeper parts of the basin and usually remain flooded till late summer or fall. Because of annual variations in precipitation, these wetlands experience substantial variation in yearly flooding frequency and depth. The deepest zones in permanent or Class V wetlands are too deep to support emergent growth, thus they are characterized by an open water area. These open water areas often conceal extensive submergent vegetation growth. A number of deep water reservoirs have also been constructed for irrigation and recreational activities. Wetland vegetation may occur around the edges or in arms or bays of the lake, but the majority of these lakes are too deep for successful growth of submergent vegetation.

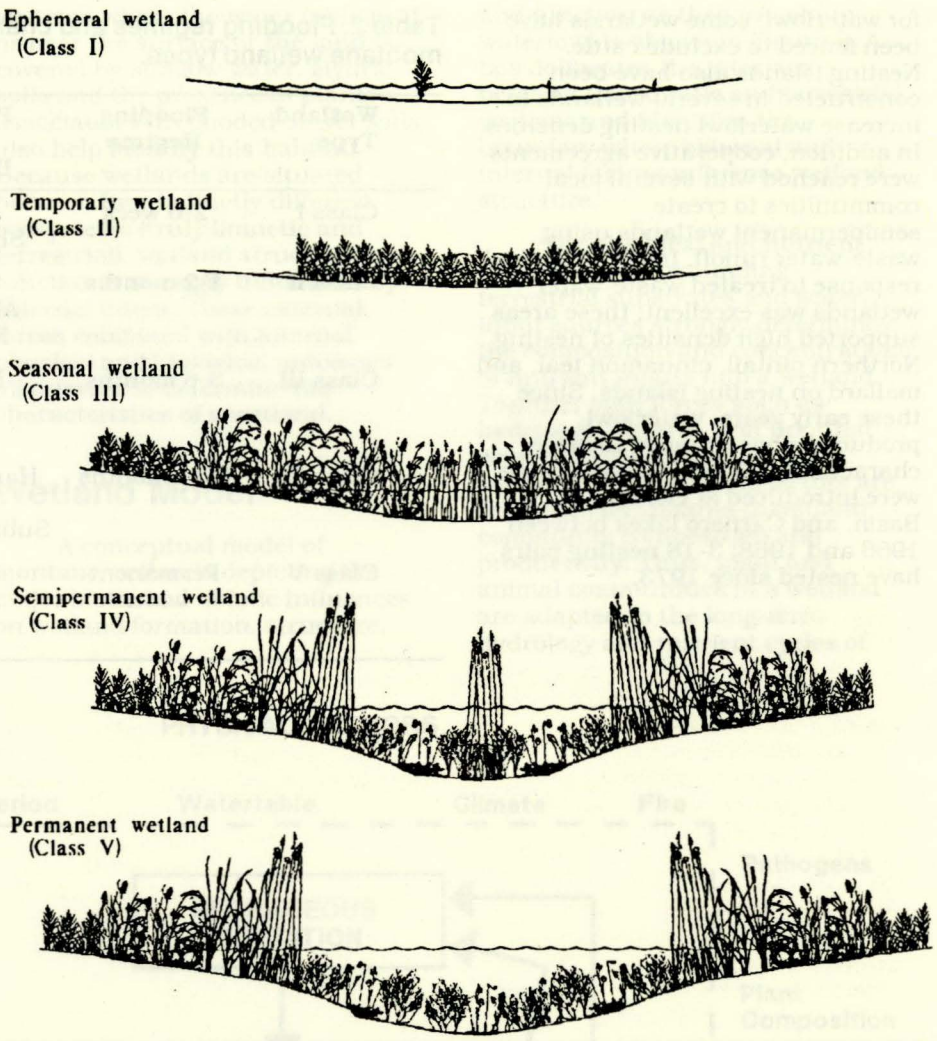



**Figure 4.** Natural wetland basin types in montane areas of Arizona.

Temporary, seasonal, and semipermanent wetland basins occur in montane areas (Table 2). Almost 90% of all Class III and IV wetland basins on Forest Service lands occur in the Apache, Sitgreaves, and Coconino National Forests (Table 1). The number of temporary wetlands, which retain water for very short periods and only in some years, is unknown.

## Current Use And Management

Wetlands on national forests are subject to public use and a variety of forest management practices. Besides the practices associated with timber harvest, grazing by livestock is extensive. To insure adequate water is available to cattle, stock tanks have been created by building small levees around or digging in natural wetland basins. Both practices prolong the period of flooding. These stock tanks often are subject to heavy grazing pressure leaving shorelines and the wetlands devoid of vegetation.

Other activities also influence the value of wetlands for wildlife. Recreational activities such as hunting, birding, and fishing are increasing as people from the growing metropolitan areas of Phoenix and Albuquerque seek the cool summer temperatures in these montane areas. Disturbance can impact wetland use by wildlife and compromise the potential for a species to complete important life cycle events.

A review of the value of montane wetlands for waterbirds concluded the lack of nest sites was the factor most limiting nesting densities of waterfowl. In an effort to increase nesting habitat quality

for waterfowl, some wetlands have been fenced to exclude cattle. Nesting islands also have been constructed in several wetlands to increase waterfowl nesting densities. In addition, cooperative agreements were reached with several local communities to create semipermanent wetlands using waste-water runoff. Initial waterfowl response to treated waste-water wetlands was excellent; these areas supported high densities of nesting Northern pintail, cinnamon teal, and mallard on nesting islands. Since these early years, waterfowl production has dropped to more characteristic levels. Canada geese were introduced at Geneva, B, Basin, and Carnero lakes between 1966 and 1968; 3-18 nesting pairs have nested since 1973.

**Table 2. Flooding regimes and characteristic plant species of three montane wetland types.**

| Wetland Type | Flooding Regime | Plant Species Occupying Deepest Zone | Flooding Frequency |
|---|---|---|---|
| Class I | 2-6 week | Bare soil;<br>Short vegetation | 3-10 years |
| Class II | 1-2 months | Salt grass<br>Alpine timothy<br>Foxtail barley | 3 of 10 years |
| Class III | 3-6 months | Manna grass<br>Spikerush<br>Carex | <7 of 10 years |
| Class IV | 6-12 months | Hardstem bulrush<br>Cattail<br>Submerged aquatics | >7 of 10 years |
| Class V | Permanent water | Submergent vegetation;<br>bare soil | Every year |

# Wetland Ecology

Maximizing regional waterfowl use requires a basic understanding of waterfowl and wetland ecology. Foremost is that waterfowl have changing habitat and nutritional needs at different times in the annual cycle and their behavior, physiology, and morphology have evolved to enable them to successfully exploit resources available in wetland plant and invertebrate communities. These important food organisms themselves evolved to survive the hydrologic, chemical, and biotic conditions of natural wetland systems. Thus, understanding the processes that govern wetland formation, function, and structure is essential for meeting long-term management objectives.

Wetlands are defined as transitional habitats situated between aquatic and terrestrial systems where the water table is at or near the surface or the land is covered by shallow water. Hydric soils and the presence of plants associated with flooded or wet soils also help identify this habitat. Because wetlands are situated between two distinctly different ecosystems (truly limnetic and terrestrial), wetland structure and function is strongly influenced by external forces. These external forces combined with internal physical and biological processes all interact to determine the characteristics of a wetland.

## Wetland Model

A conceptual model of montane wetlands depicting the major biotic and abiotic influences on wetland formation, structure, and function as they pertain to waterfowl is shown in Figure 5. A box delineates the interface between the aquatic and terrestrial systems and identifies the boundary where external and internal factors influence wetland structure.

The chemical and nutrient properties of surrounding terrestrial substrates and water input sources strongly determines the composition and concentrations of nutrient inputs into a wetland. Together with forces such as hydrology, climate, and fire, that govern the rate and timing of nutrient delivery, these factors are the key determinants of wetland community composition and productivity. Thus, plant and animal communities in a wetland are adapted to the long-term hydrology and nutrient cycles of

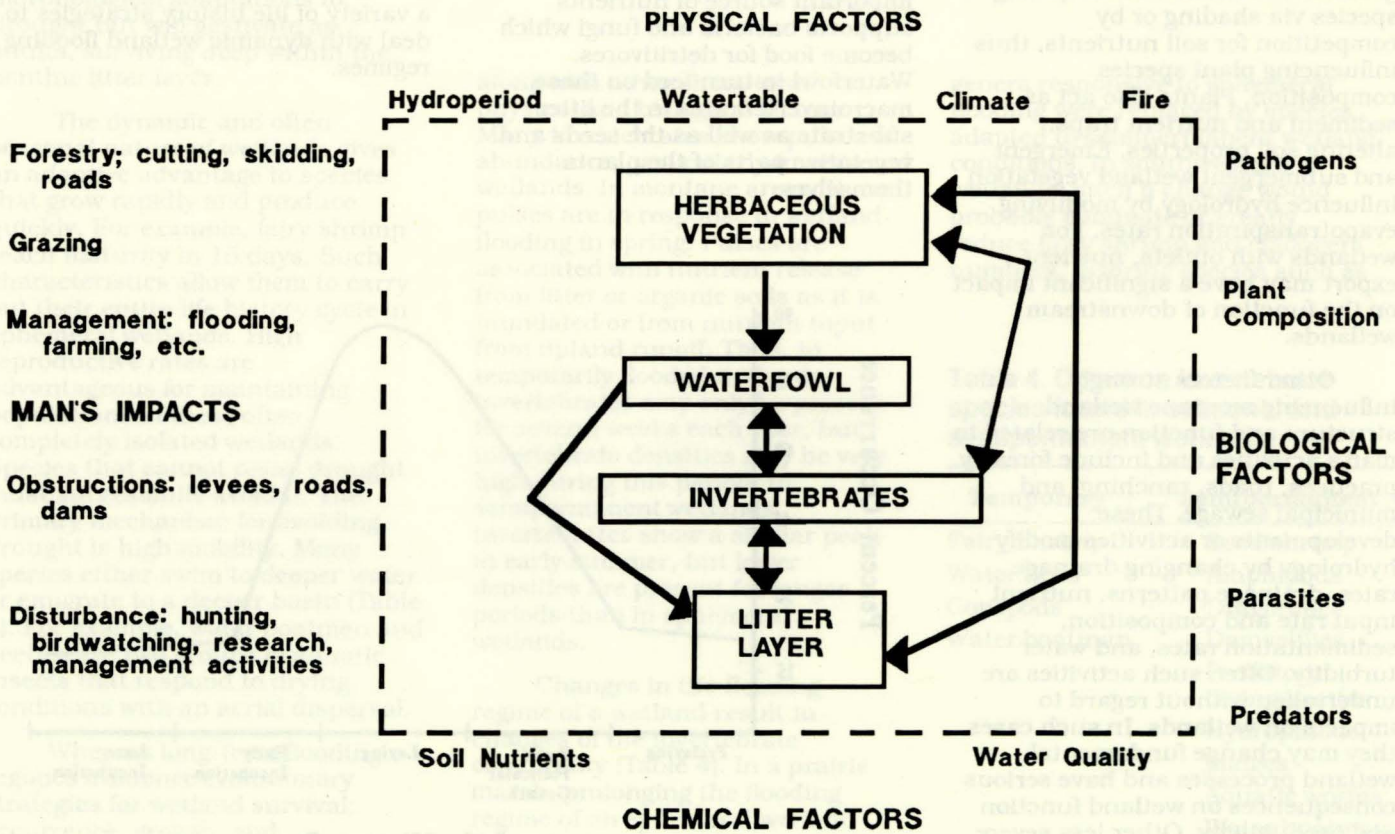



**Figure 5.** Conceptual model depicting the major biotic and abiotic components influencing wetland structure and function.

that wetland.

Biological factors such as predators, herbivores, parasites, and pathogens have an impact on wetland plant and animal community structure via competition, predation, and disease. Animals directly impact wetland structure and macrophyte composition through grazing and selective seed predation. They also have an indirect impact via nutrient inputs in the form of urine and feces.

Once established, wetland plant and animal communities in turn modify the physical, chemical, and biotic processes that were responsible for creating the wetland. Plants and microbes can modify soil redox potential by modifying soil oxidation conditions, which can affect plant communities. Dense plant growth, both above and below ground, can choke out competing species via shading or by competition for soil nutrients, thus influencing plant species composition. Plants also act as sediment and nutrient traps, altering soil properties. Emergent and submergent wetland vegetation influence hydrology by modifying evapotranspiration rates. For wetlands with outlets, nutrient export may have a significant impact on the function of downstream wetlands.

Other factors strongly influencing montane wetland structure and function are related to man's activities and include forestry practices, roads, ranching, and municipal sewage. These developments or activities modify hydrology by changing drainage rates, drainage patterns, nutrient input rate and composition, sedimentation rates, and water turbidity. Often such activities are undertaken without regard to impacts on wetlands. In such cases, they may change fundamental wetland processes and have serious consequences on wetland function and productivity. Other less severe human activities that can affect waterfowl use of wetlands are disturbance associated with hunting, nonconsumptive recreation, and research activities. Trout stocking is common in some of the deeper wetlands. Fishing disturbs waterbirds and fish are competitors for invertebrate foods used by waterbirds.

Three internal components of montane wetlands closely associated with waterfowl use are: herbaceous vegetation, detritus, and macroinvertebrates (Fig. 5). Moist-soil and aquatic macrophytes that comprise the herbaceous vegetation component of a wetland provide cover, energy, and food for waterfowl as well as providing substrate for macroinvertebrates. Moist-soil plant foods that attract waterfowl are produced on exposed mud flats when surface water disappears during natural draw downs. Invertebrates colonize these areas upon reflooding. Senescence of macrophytes produces litter. This important source of nutrients supports bacteria and fungi which become food for detritivores. Waterfowl in turn feed on these macroinvertebrates in the litter substrate as well as the seeds and vegetative parts of the plants themselves.

## Macroinvertebrates

Macroinvertebrates occur in the litter layer and among the leaves and stems of emergent and submergent vegetation. Many species of waterbirds rely on invertebrates as food. Waterfowl heavily utilize invertebrates during certain periods of the annual life cycle when proteinaceous foods are needed, specifically during egg laying, as young ducklings, and molt (Fig. 6). Invertebrates are also important in the transformation and translocation of nutrients in a wetland. For example, benthic chironomids release phosphorus from sediments while burrowing. Phosphorus is an important, often limiting, nutrient for plant growth. Thus, invertebrates form an important link in nutrient movement from detritus to plant and waterfowl use. As with wetland plants and animals, invertebrates have adapted a variety of life history strategies to deal with dynamic wetland flooding regimes.

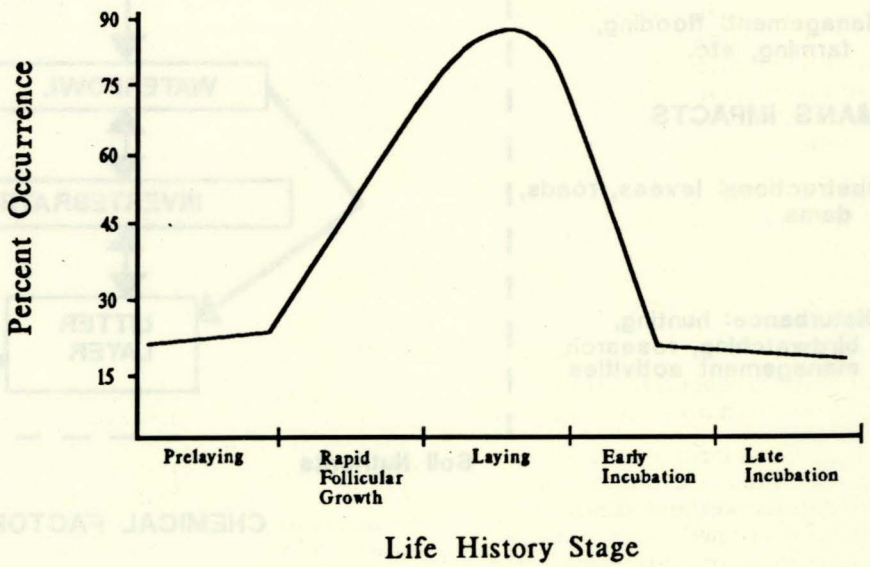



**Figure 6.** Percent invertebrates in the diets of female mallards during different periods of the nesting cycle.

## Adaptation and Response to Wetlands

Adaptive strategies typically develop that have allowed invertebrates to either tolerate or avoid drought. Some of the adaptations that are characteristic of these strategies include: (1) the ability to withstand drought in the egg, pupal, or larval stage; (2) rapid growth; (3) the ability to produce numerous offspring; (4) compressed life cycle; and (5) high mobility.

Drought resistance is an important component of many invertebrate life cycles, and characterizes species with poor mobility (Table 3). Mosquitoes, water fleas, and fairy shrimp all have drought resistant eggs. Oligochaetes may use mucosal secretions to survive drought while some chironomids aestivate in cocoons. Amphipods have no morphological adaptations to drought but will aestivate as adults, surviving deep within the benthic litter layer.

The dynamic and often seasonal nature of wetlands gives an adaptive advantage to species that grow rapidly and produce quickly. For example, fairy shrimp reach maturity in 15 days. Such characteristics allow them to carry out their entire life history cycle in ephemeral wetlands. High reproductive rates are advantageous for maintaining populations in these often completely isolated wetlands. Species that cannot resist drought must successfully avoid it. The primary mechanism for avoiding drought is high mobility. Many species either swim to deeper water or emigrate to a deeper basin (Table 3). For example, water boatmen and beetles are two groups of aquatic insects that respond to drying conditions with an aerial dispersal.

Whereas long-term flooding regimes influence evolutionary strategies for wetland survival; occurrence, growth, and reproduction are influenced by the timing and duration of yearly floods along with other short-term physical and biological factors. Many invertebrates show pulses of abundance, particularly in seasonal wetlands. In montane areas, these pulses are in response to wetland flooding in spring. Pulses are associated with nutrient release from litter or organic soils as it is inundated or from nutrient input from upland runoff. Thus, in temporarily flooded wetlands invertebrates may only be present for several weeks each year, but invertebrate densities may be very high during this period. In semipermanent wetlands, invertebrates show a similar peak in early summer, but lower densities are present for longer periods than in ephemeral wetlands.

Changes in the flooding regime of a wetland result in changes of the invertebrate community (Table 4). In a prairie marsh, prolonging the flooding regime of an ephemeral wetland caused a loss in over half of the original invertebrate genera. Those genera responsive to ephemeral flooding were replaced by species adapted to semipermanent wetland conditions. In southwestern wetlands, such a change would probably eliminate or greatly reduce fairy shrimp and cladocera numbers, favoring species such as

**Table 3. Classification of major montane invertebrate species based on tolerance or avoidance of drought.[1]**

| Overwintering Residents | Overwintering Spring Recruits | Overwintering Summer Recruits | Non-wintering Spring Migrants |
|---|---|---|---|
| Amphipods | Predatory Beetle | Dragonflies | Hemipterans |
| Aquatic worms | Horseflies | Midge larvae | Some odonates |
| Midge larvae | Midge larvae | Damselflies | Some dipterans |
| Fairy shrimp | Scavenger beetle | | |

[1] Tolerance of drought defined as follows (after Wiggins et al. 1981):

Overwintering residents: These animals are capable of passive dispersal only and overwinter as drought-resistent cysts and eggs or as juveniles or adults.

Overwintering spring recruits: These animals must reproduce in the spring before surface water disappears. They aestivate and overwinter as eggs or larvae, but as adults in some beetle species.

Overwintering summer recruits: These animals can enter basin after surface water disappears. They overwinter as eggs or larva within egg matrix.

Nonwintering spring migrants: These animals enter surface water in spring. Adults of subsequent generations leave basin before drydown and overwintering is in permanent water.

**Table 4. Common invertebrate species found in seasonal and semipermanent wetlands.**

| Temporary | Semipermanent |
|---|---|
| Fairy Shrimp | Seed shrimp |
| Water fleas | Amphipods |
| Copepods | Dragonflies |
| Water boatman | Damselflies |
| | Predatory diving beetles |
| | Hydrophilids |
| | Midges |
| | Aquatic worms |
| | Water boatman |
| | Mayflies |
| | Snails |

amphipods, dragonflys and snails (Table 4). This illustrates an important management point. Retaining water for longer periods with the objective of prolonging or increasing invertebrate populations may in fact cause their demise.

## Invertebrate Habitats

Plant species composition and distribution within a wetland have an important impact on invertebrate density and diversity. Plants with large numbers of finely dissected leaves like smartweeds, watermilfoil, and bladderwort support higher invertebrate densities in the water column than plants like spike rush or hardstem bulrush that have smooth stems. The growth form of these plants provides increased surface area for shelter and foraging. Furthermore, the lower cellulose content in the leaves make them superior food for detrivores as compared to bulrush or spikerush. However, a patchwork of the submergent and emergent species mentioned will support higher invertebrate densities than a monotypic stand of either. Emergents like spike rush and bulrush are believed to shelter areas from wind action, while the submergents provide the optimal invertebrate substrate. In montane wetlands, benthic litter, floating litter, and submergent and emergent aquatic macrophytes provide excellent substrates for invertebrate communities.

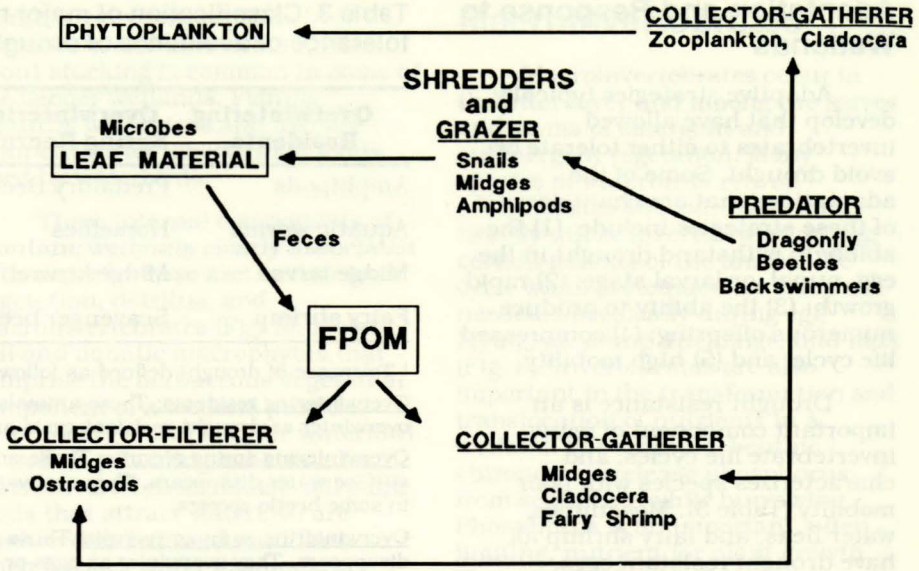



**Figure 7.** Interactions among major invertebrate functional groups in montane wetlands.

**Table 5. Classification of montane wetland invertebrates based on feeding mechanisms.[1]**

| Shredder | Collector Gatherer | Collector Filterer | Predator | Scrapers (grazers) |
|---|---|---|---|---|
| Amphipods | Scavenger beetles | Midges | Dragonfly | Snails |
| Cranefly | Midges | Water boatman | Damselfly | Midges |
| | Cladocera | Seed shrimp | Predatory beetle | Mayflies |
| | Fairy shrimp | | Backswimmer | |

[1] Feeding mechanisms defined as follows (after Merrit and Cummins 1978):

Shredders: Herbivores living on plant tissue or detritivores decomposing plant tissue (CPOM) by chewing.

Collector-filterer: Living on algal cells or decomposing organic matter (FPOM) primarily by filter or suspension feeding.

Collector-gatherer: Detritivore living on decomposing organic matter (FPOM) primarily by sediment or deposit feeding.

Predators: Carnivores living on whole animals or parts.

Scrapers: Herbivores living on algae and associated material primarily by scraping plant surface.

## Invertebrate Communities

Food availability and foraging mechanisms strongly influence invertebrate community organization (Table 5). The litter layer is dominated by a detritivore community (Table 6). Shredders, including amphipods, commonly feed on coarse (large) particulate organic matter (CPOM). Shredders impact litter decomposition and nutrient cycling by fragmenting litter. As organic matter is broken down into fine (small) particulate organic matter (FPOM), it becomes available to organisms that gather detritus or filter feed (Fig. 7).

In contrast to the detritivore community in benthic habitats, invertebrates utilizing submergent or emergent vegetation are most often grazers or collector gatherers. Species like snails, water boatmen, and midge larvae feed on algae, suspended organic matter or the

**Table 6. Location within a wetland of some common invertebrates of montane wetlands.**

| Benthic (mud, litter) | Watercolumn (submergent vegetation) |
|---|---|
| Scuds, Sideswimmers *(Amphipoda)* | Dragonfly nymphs *(Odonata)* |
| Predatory diving beetle larvae *(Dystisidae)* | Mosquito larvae *(Cuicidae)* |
| Midge larvae *(Chironomidae)* | Predatory diving beetle adult larvae *(Dystisidae)* |
| Aquatic worms *(Oligochaeta)* | Midge larvae *(Chironomidae)* |
| Snails *(Gastropoda)* | Backswimmer *(Notonectidae)* |
| Seed Shrimp *(Ostracods)* | Damselfly larvae *(Odonata)* |
| | Snails *(Gastropoda)* |
| | Fairy shrimp *(Anostraca)* |
| | Water fleas *(Cladocera)* |
| | Copepods *(Copepoda)* |
| | Water scavenger beetle *(Hydrophilidae)* |
| | Water boatman *(Corixidae)* |

plant itself. These species may inhabit the water column around the plants actively searching for food, search for food along the plant itself, or anchor themselves to the plant and feed in the water column. Predatory species like beetles and dragonflies can occur wherever sufficient numbers of prey items exist.

## Wetland Structure

Montane wetlands are dominated by herbaceous monocots in the grass and sedge families. The complete absence of trees in most of these wetlands creates a low vertical vegetation profile. The distribution of wetland plants is strongly controlled by hydrology. Figure 8 shows several common montane wetland plant species and their relation to flooding depth and permanence. In the field, it is possible to predict the flooding regime of a previously unseen wetland by studying the type and distribution of its vegetation. Vegetation may occur in concentric rings, or zones, around the wetland corresponding to the wetland flooding gradient.

Wetlands with permanent water support submergent plant species like water milfoil, bladderwort, and waterweed. The buoyancy of water reduces the need for structural support in these plants, allowing both leaves and stems to specialize in the task of gas and nutrient exchange with the water. Relatively little biomass is put into roots, and many species survive well, suspended in the water column. These species recolonize after periodic droughts by sprouting from seeds.

Bulrush and cattail species are adapted to semipermanent wetlands with water most of the year. Unlike most other wetland plant species, these perennials have large root/shoot biomass ratios (Table 7). The root mass can be so large that it prevents the establishment of other plant species. These species frequently grow in anoxic soil, which poses a problem for root survival. They have adapted to these anoxic conditions by transporting atmospheric oxygen taken up by the leaves, through specialized cells to the roots. Although these species produce large numbers of seeds, they typically spread by creeping rhizomes. Seeds may be more important for colonizing other wetlands or for reestablishing colonies after exceptionally long drought periods. Under normal flooding cycles, these robust emergents die back during drought conditions and resprout from the roots upon reflooding.

At slightly higher elevations within a semipermanent wetland or in seasonal wetlands, species like spike rush and water plantain thrive. Spike rushes are perennials and ecologically similar to the more robust bulrushes. Millet, salt grass, and manna grass occupy the next zone. Most species in this zone are annuals and are reestablished each spring from seeds. In most areas immediately above the cattail zone, a variety of dominant species are in the genera Carex and Cyperus. The specific species present depends on the local flooding conditions. In Arizona, beaked sedge and water

**Table 7. Root to shoot standing crop estimates for several species of common wetland plants.**

| Species | Above ground (g/m2) | Below ground (g /m2) | Below/Above |
|---|---|---|---|
| Hardstem Bulrush | 950 | 1500 | 1.6 |
| Cattail | 2,000 | 3,200 | 1.1-3.1 |
| Carex | 1,640 | 328 | 0.2 |
| Juncus | 1,592 | 267 | 0.17 |

sedge are the most prevalent. Often times different plant species dominate the higher or less frequently flooded wetland zones in different years. Such differences in plant composition result from annual variations in the timing of water draw down and associated ambient soil temperatures that favor the germination of different species among years.

## Wetland Succession

Originally, wetlands were viewed as immature stages of an ecological process that results in the development of a climax terrestrial forest community. This process was driven by peat accumulation which eventually filled in wetland basins, favoring more xeric plant species. While there is evidence to support this view in some wetlands, in most cases their is evidence of a concomitant lowering of the water table. Some wetlands have persisted for over 100,000 years, with only changes in dominant wetland plant communities. Recognizing this fact, a more plausible model was created to explain vegetational changes in wetlands.

The current theory recognizes that different plant species are adapted to different soil, hydrologic, and nutrient conditions. As these abiotic characteristics change over time for a wetland, so does plant species composition. Thus, wetlands with stable environmental regimes can persist indefinitely, but vegetational composition changes in relation to changing chemical and structural aspects of the wetland. The theory also eludes to the catastrophic effects which can result from changes in abiotic factors such as ground water level and nutrient flow.

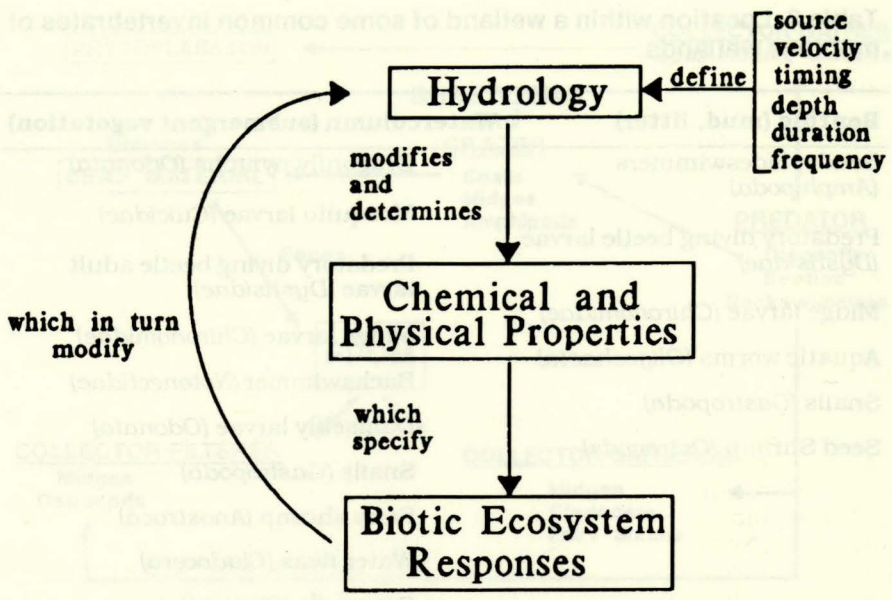



**Figure 9.** Conceptual diagram illustrating the role of hydrology in the formation and function of a wetland.

# Wetland Function

## Hydrology

The seasonal and yearly fluctuations of wetland water levels, called a wetland's hydroperiod, is the single most important factor driving the creation and maintenance of specific wetland types, and the structure and composition of wetland plant and animal communities (Fig. 9). Hydroperiod controls nutrient flow, substrate anoxia, soil

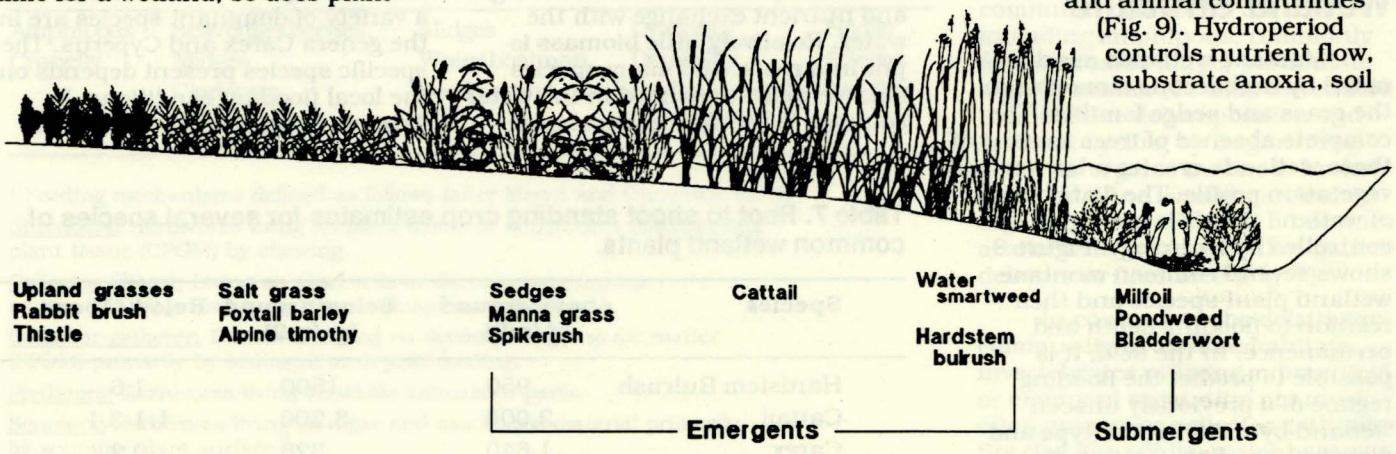



**Figure 8.** Location of wetland plants in relation to flooding depth and permanence.

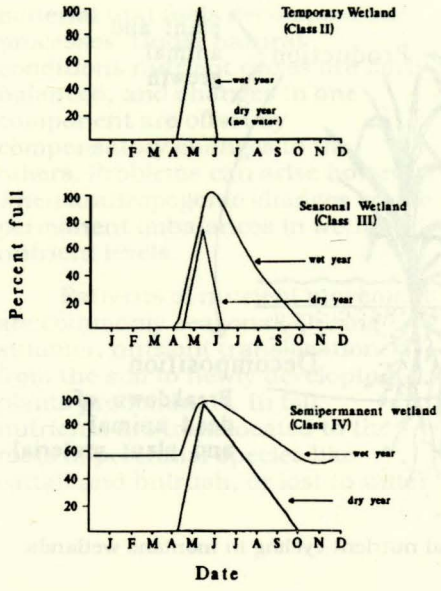



**Figure 10.** Range of flooding regimes characteristic of three types of montane basinal wetlands.

salinity, sedimentation properties, and pH. These factors in turn influence productivity, decomposition rates and nutrient cycling.

Long-term trends in hydroperiod are an important ultimate factor driving the evolution of adaptive strategies by wetland plant, invertebrate and vertebrate species (Fig. 10). In contrast, annual variation in precipitation influences the timing, extent, and duration of flooding that provides proximate cues for the timing of biological events. Because most montane wetlands are isolated basins, they are dependent on localized precipitation for water inputs. The frequency and extent of flooding is strongly affected by the size of the watershed that drains the wetland and by elevation which affects precipitation amounts, freezing dates, and evapotranspiration rates. Some wetlands receive water from natural springs, thus changes in ground water levels or quality can have additional effects on wetland hydrology.

The form and timing of precipitation has different impacts on wetlands. Most precipitation from October to March falls as snow. Subsequent melting of the snow pack in April causes a single large, rapid input of water and nutrients into montane wetlands. The result in spring is a reflooding of dried seasonal wetlands and excellent nutrient availability for plant and invertebrate communities in semipermanent wetlands occurring over a large geographic area.

Summer precipitation, resulting from moist air drawn into Arizona from the Gulf of Mexico, occurs primarily as thunderstorm events. These thunderstorms are capable of dropping significant amounts of precipitation in a short period of time, but they typically occur on a much more localized scale. These localized events create water and nutrient pulses into a wetland, each wetland potentially receiving many such pulses throughout the summer. The timing and extent of these pulses varies among wetlands because of differences in elevation and location. This variation in water regimes cause variation in the timing, extent, and nature of plant and animal community responses.

## Soils

Soils are an important component of wetlands because they store nutrients used by macrophytes and invertebrates and serve as a medium for many of the chemical processes occurring in a wetland. Wetland soils differ from surrounding upland soils by having a higher clay content, more organic matter, higher water holding capacity, and greater redox potential. The nature of these soils changes with elevation, hydrology, and type of parent material from which they were derived. Flooding usually creates anoxic soil conditions in all but a thin top layer. Soil oxygen levels strongly affect the availability of plant nutrients and toxic materials in the soil. Some of the most important nutrients influenced by soil conditions are nitrogen, phosphorus, iron, manganese, sulfur, and carbon.

## Decomposition

Decomposition is the mineralization of organic matter. In undisturbed montane wetlands herbivory is relatively minor, and a majority of organic material undergoes microbial decomposition. Thus, litter decomposition rate regulates the release of nutrients that are available to plants. The microbes that perform the breakdown process also become the first link in a food chain that results in waterfowl food production.

Temperature, pH, and the frequency and extent of flooding are the most influential factors governing decomposition rates of specific plant species (Fig. 11). By influencing soil and water oxygen levels,

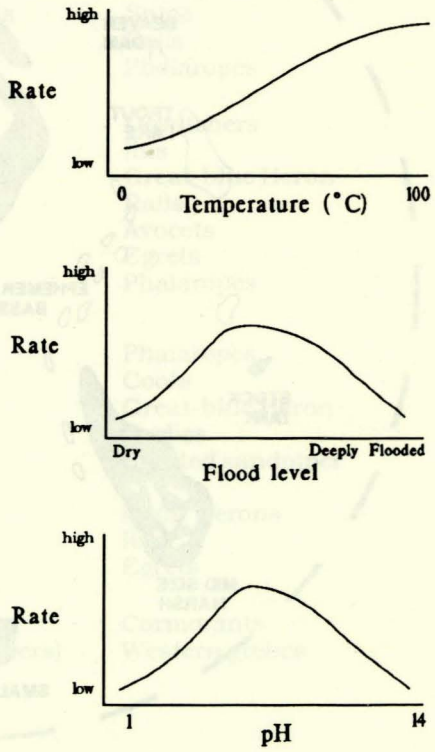



**Figure 11.** General influence of temperature, moisture, and pH on decomposition rates.

these three factors determine the microbial community that carries out decomposition and whether the process follows aerobic or anaerobic metabolic pathways. Aerobic processes are faster and more efficient than anaerobic processes. Prolonged anaerobic conditions usually lead to a buildup of peat caused by incomplete breakdown of organic matter. Inherent structural differences among plant species, specifically the Carbon:Nitrogen ratio, largely explain differences in decomposition rates. At certain times of the year or under certain flooding conditions, decomposition rate may create a nutrient bottleneck thereby controlling organism growth in montane wetlands.

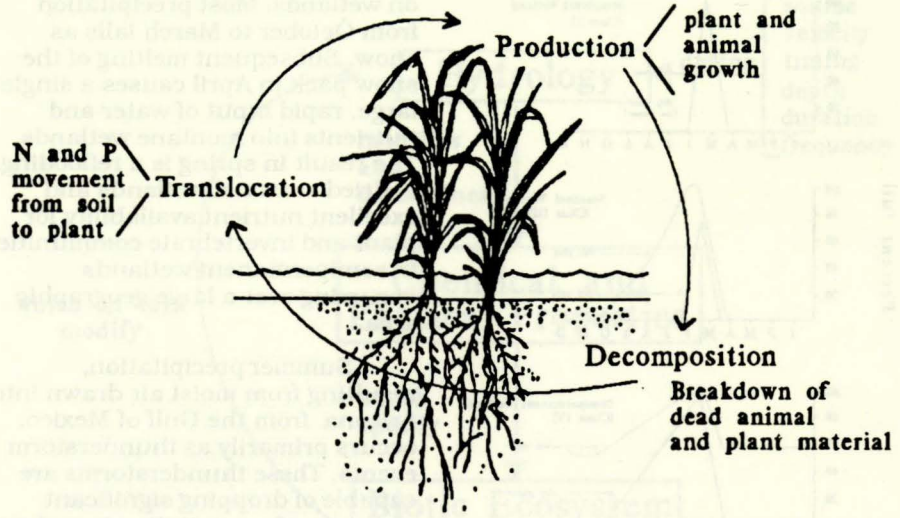



**Figure 12.** Three major components of internal nutrient cycling in montane wetlands.

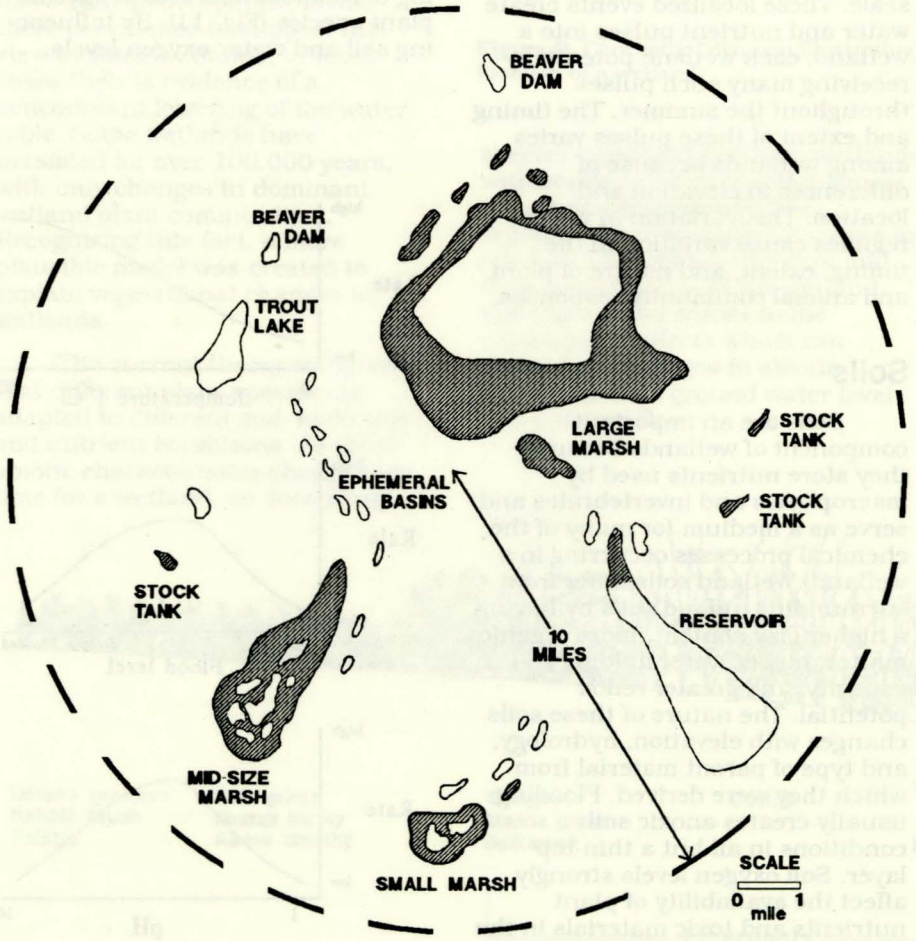



**Figure 13.** Hypothetical types and distribution of wetlands within a Montane Wetland Complex.

## Nutrient Cycling

Nutrient cycling can be viewed as two processes—external and internal. External cycling refers to inputs into a wetland from external sources and outputs from the wetland to adjacent habitats. Major input sources include the atmosphere (rain/dust), ground water, bedrock/soil, and organic sources. In open wetland systems, external nutrient processes dominate productivity rates. Because external processes generally create higher nutrient input and turnover rates, open wetland systems are more productive than isolated basins, or closed systems because they are connected to input and output water sources.

Most montane basins are closed systems, hence internal nutrient cycling processes such as litter production, decomposition, and translocation are more important in determining productivity (Fig. 12). Translocation involves removal of nutrients from the soil or water column by roots and leaves, and converting these nutrients into plant tissue or storing them in roots prior to plant senescense. Litter production and senescence provides the organic

material that fuels decomposition processes. Under natural conditions nutrient cycles are fairly balanced, and changes in one component are offset by compensatory changes in the others. Problems can arise however, when anthropogenic changes create permanent imbalances in wetland nutrient levels.

Patterns of nutrient movement are commonly seasonal. During summer, nutrient translocation from the soil to newly developing plants predominate. In fall, nutrients are translocated to the roots of perennial species like cattail and bulrush, or lost to water and soil when the leafy portion of wetland plants senesce.

## Wetland Complexes

Wetland basins can be thought of as distinct entities, but it is much more appropriate from a biological and management perspective to think of complexes of wetlands within a region (Fig. 13). As mentioned earlier, different wetland types provide different resources at different times of the year to a variety of organisms (Table 8). Spatial relationships among wetlands then become very important in determining the distribution of organisms in an area (Fig. 13). As an example, a female mallard may nest near a semipermanent wetland because of the excellent brood habitat it provides, but she may choose a nearby seasonal wetland for loafing and feeding during egg laying and incubation because of higher invertebrate densities or better isolation. That same seasonal wetland provides excellent habitat for migrating sandpipers and breeding avocets that can not use the de deeper semipermanent wetland. Thus, successful management for a diversity of waterbirds requires both types of wetlands.

**Table 8. Availability and use of different wetland types by waterbird species.**

| Wetland Type | Availability | Use By Waterfowl | Other Waterbird Use |
|---|---|---|---|
| Temporary | Early spring | Pair water<br>High density invertebrate foods<br>Molting | Avocets<br>Snipe<br>Rails<br>Phalaropes |
| Seasonal | Spring | Pair water | Dowitchers<br>Ibis |
| | Summer | Nesting (dabblers)<br>Brood rearing (dabblers)<br>Molting | Great-blue Heron<br>Rails<br>Avocets<br>Egrets<br>Phalaropes |
| Semi-permanent | Spring | Molting<br>Pair water (divers)<br>Courtship (divers)<br>Nesting (divers, dabblers) | Phalaropes<br>Coots<br>Great-blue Heron<br>Grebes |
| | Summer | Brood habitat<br>Wing molt | Spotted sandpiper |
| | Fall | Molt | Night Herons<br>Ibis |
| | Fall Migration | Staging | Egrets |
| Permanent (Reservoirs or large lakes) | All year | Roosting<br>Foraging (some divers, mergansers) | Cormorants<br>Western grebes |
| Beaver pond | Variable | Pair water<br>Limited nesting | |

Montane wetlands support a diverse array of animal species. Some depend on wetlands for all aspects of their annual life cycle, whereas others exploit seasonal resource availability and others are strictly transient, exploiting wetlands opportunistically during the year. These species have adapted behavioral, morphological, and physiological traits which allow them to utilize the resources in highly dynamic wetland systems. Spatial and temporal variation in the use of these resources accounts for the high number of species that exploit wetlands during at least some portion of the year.

## Waterfowl

### Life History Strategies

Fourteen species of ducks regularly use southwest montane wetlands. These waterfowl species have diverse requirements for survival and reproduction. No single wetland can meet the needs of all species during a season, nor can any single wetland meet the needs of a single species all year long. Effective management of montane wetlands for all waterfowl species requires an understanding of waterfowl ecology and how that ecology is influenced by spatial and temporal changes in hydrology, food abundance, food availability, and habitat structure.

**Table 9. Life history events in the annual cycle of waterfowl using the mallard as an example.**

| |
|---|
| Spring migration |
| Reproduction |
| Pre-laying - endogenous lipid reserves |
| Laying - endogenous or exogenous proteins |
| Incubation |
| Brood rearing |
| Summer molt |
| Staging |
| Fall migration |
| Pairing |
| Molt |
| Endogenous reserve deposition |

### Annual Cycle

Throughout the year waterfowl undergo a series of biological events that are closely tied to changing hydrology, food availability, and vegetation within wetlands (Table 11). Seasonal changes in climate necessitate that many waterfowl exploit wetlands on a continent-wide basis to successfully complete these processes. Because of this spatial segregation in the timing of biological events, the tendency is to think of them as discrete processes that are independent from one another. Out of necessity, most research must adopt this approach and thus the literature tends to reflect this compartmentalized view of waterfowl life history events. In truth, all life history events are dependent and several may occur simultaneously. For any one individual, the timing of one event depends on the initiation and duration of the previous event. Variations in timing and duration of these events reflect both basic differences among taxonomic groups of birds (e.g., divers vs. dabblers) as well as differences in age, sex, and physiological condition of individuals within a species.

As an example of the interdependence of biological events, consider the factors which interact to influence first clutch size in female mallards. Clutch size is directly correlated with the level of endogenous lipid reserves a female possesses upon arrival at the breeding grounds. Lipids are important in spring because they provide energy for egg production and daily maintenance requirements.

The level of a female's stored lipid reserves depends on a variety

**Table 10. Chemical composition of some common waterfowl plant foods. Values represent averages from the literature.**

| Common Name | Part | Gross Energy (kcal/g) | Percent Fat | Percent Fiber | Percent Ash | Percent NFE[1] | Percent Protein |
|---|---|---|---|---|---|---|---|
| Algae | Vegetation | 3.2 | | 17.8 | | | 14.4 |
| Muskgrass | Vegetation | 2.6 | 1.4 | 15.2 | 30.4 | 48.4 | 5.2 |
| Chufa | Tubers | 4.3 | 6.9 | 9.0 | 2.5 | 55.4 | 6.7 |
| Barnyardgrass | Seeds | 4.1 | 2.88 | 19.0 | 13.1 | 50.6 | 11.7 |
| Pondweeds | Seeds | | 3.0 | 18.4 | 2.8 | 65.9 | 10.2 |
| Mannagrass | Seeds | | 1.4 | 7.9 | 8.5 | 76.1 | 6.0 |
| Water milfoil | Vegetation | 2.59 | 1.3 | 14.1 | 18.2 | 49.9 | 17.4 |

[1] Nitrogen Free Extract

of biotic and abiotic factors. Females that complete the pre-basic molt earlier in spring have more time to store endogenous lipid reserves. Adults typically initiate the pre-basic molt earlier in winter than immatures, which may occur because adult females reach a threshold weight necessary to initiate molt earlier than immatures. Differential weight gain among age groups is related, among other things, to pair formation chronology. Adults pair earlier than immatures and paired birds dominant preferred feeding sites, allowing paired females to gain weight faster.

This entire network of biotic interactions is superimposed on a larger framework of habitat quality which is strongly influenced by precipitation. Poor habitat quality during any or all seasons both retards the onset and prolongs the duration of certain biological events which ultimately can decrease stored lipid levels in spring, resulting in a smaller clutch size. Years or seasons with good habitat quality allow for earlier initiation and shortened duration of these same events. During these years, females have more time or better opportunities to store lipids before arrival at breeding areas, leading to increased clutch size.

The above example is an over-simplification but it serves to illustrate the complexity and interdependence of seemingly disjunct biotic and abiotic phenomenon.

## Nutrition

During the annual cycle waterfowl have different nutritional and energetic needs. They meet these needs by relying on a variety of foods that are acquired from different wetland types or different vegetation zones within a wetland basin. Information needed to assess the value of potential foods includes metabolizable energy, fat, fiber, ash, nitrogen free extract (NFE), and protein composition. Little work has been done on the metabolizable energy of wild foods, thus managers are forced to use gross metabolizable energy derived from bomb calorimetry in the lab as a guide. Fats are the most concentrated energy sources in foods, slightly higher than NFE which represents the highly digestible carbohydrate component.

**Table 11. Chemical composition of some common waterfowl invertebrate foods.**

| Common Name | Gross Energy (kcal/g) | Protein (Percent) |
|---|---|---|
| Spiders | 5.0 | 75.8 |
| Water boatmen | 5.2 | 71.4 |
| Backswimmers | 5.7 | 64.4 |
| Midges | 4.6 | 61.2 |
| Copepods | 4.6 | 58.1 |
| Water fleas | 4.0 | 49.7 |
| Scuds | 3.8 | 47.0 |
| Snails | 1.0 | 14.2 |

Fiber is the least digestible component of food with little value to waterfowl who lack the ruminating capabilities of other ungulates. Ash is the mineral content of food, and proteins are nitrogen containing compounds which are the primary component in muscle, feather, enzymes, and hormones.

The limited information available for waterfowl foods reveals a wide range of nutritional value (Table 10 and Table 11). In general, seeds and tubers are high in carbohydrates and invertebrates are high in protein. Unfortunately, little work has been done on the metabolizable energy available to waterfowl derived from these various foods. Chemical analysis of foods can be misleading because the functional energy and nutrient availability of a food to a duck may be substantially different than its apparent availability in the lab (Table 12.) For example, comparing gross and metabolizable energies of several foods shows the disparity in metabolizable energy among foods with similar gross energies (Table 12). High gross energy foods like scuds and big-seeded smartweed have much lower metabolizable energy than rice cutgrass and millet. Waterfowl also need a balance of amino acids and some foods like crustaceans usually have a better balance than insects or spiders.

**Table 12. Metabolizable energy of some common waterfowl foods.**

| Taxon | Test Animal | Gross Energy (kcal/g) | Metabolizable Energy (kcal/g) | Percent Usable Energy |
|---|---|---|---|---|
| Scuds | Blue-winged teal | 4.5 | 2.32 | 51.2 |
| Big-seeded smartweed | Dabbling duck (male) | 4.4 | 1.12 | 25.5 |
| Coast barnyardgrass | Duck (male) | 4.1 | 2.99 | 72.9 |
| Rice cutgrass | Duck (male) | 4.0 | 3.00 | 75.0 |
| Waterflea | Blue-winged teal | 4.0 | 0.82 | 20.5 |
| Pond snail | Blue-winged teal | 1.0 | 0.59 | 59.0 |

These nutritional differences among foods are responsible for the changing diets of waterfowl during the year. Migration and winter periods require energy for flight and thermoregulation. The best foods to meet these needs are seeds and tubers with high energy levels. During molt and egg formation, tissue synthesis is important, thus waterfowl shift their diet to incorporate more invertebrates that supply more proteins and amino acids. These differences in food quality coupled with differences in the timing of similar life history events for each waterfowl species make the job of providing adequate resource needs very complicated.

## Breeding

Mallard, northern pintail, gadwall, cinnamon teal, green-winged teal, redhead and ruddy duck are common nesting species in Arizona montane wetlands. A small population of breeding Canada geese has also been established in the White mountains of east central Arizona. Nesting chronology is strongly influenced by elevation because of temporal differences in spring thaw. Elevational differences of 1,650 feet can cause as much as a one month delay in nest initiation at the higher elevation (Fig. 14). Regardless of elevation, mallards and pintail are consistently the earliest nest initiators, whereas gadwalls and ruddy ducks are the latest. The composition of the breeding population also changes by location/altitude (Table 13). Compared to wetlands on Anderson mesa, mallards are much more prevalent at higher elevation wetlands in the White mountains, while pintail and redhead numbers decline, and all others remain similar.

**Table 13. Elevational differences in the breeding waterfowl community of Arizona montane wetlands.**

| | Elevation | |
|---|---|---|
| | <7,200 Ft. | >8,500 Ft. |
| Mallard | 9% | 22% |
| Pintail | 13% | 8% |
| Redhead | 20% | 12% |
| Other Ducks | 58% | 58% |

*Source: Myers 1982 and Piest 1982*

**Table 14. Nest site preferences for waterbirds using southwestern montane wetlands.**

| Nest Sites | Characteristic Vegetation | Species |
|---|---|---|
| *Over water at water surface* | | |
| Deep | Robust emergents | Redhead<br>Ruddy duck<br>Eared grebe |
| Deep/shallow | Robust emergents<br>Muskrat houses | American coot<br>Mallards |
| Shallow water | Robust emergents | Virginia rail<br>Sora |
| *Over-water above water surface* | | |
| Deep/shallow | Robust emergents | Yellow-headed blackbird |
| At water's edge | Robust vegetation | Red-wing blackbird (also on uplands) |
| *Upland* | | |
| Moderately near or great distance from water | Open, sparse shore vegetation | Avocet<br>Pintail |
| Moderately near water | Tall dense vegetation | Mallard<br>Gadwall |
| Near water | Dense short vegetation | Canada goose<br>Cinnamon teal |

Upon arrival at the breeding grounds, females must select suitable nest sites and acquire nutrients necessary to lay a clutch of eggs. Habitat requirements for successful nesting by most waterfowl species are good cover and isolation. Good cover protects the nest and female from mammalian and avian predation. Isolation reduces disturbances from conspecifics. Reduction of disturbance by humans or among conspecifics reduces aggression among individuals and minimizes nest failure due to desertion. Providing good nesting habitat for all waterfowl species on a wetland is somewhat difficult because they require a diverse group of plants that provide the necessary structural features (Table 14).

Large stands of robust emergent vegetation such as hardstem bulrush and cattails supply nesting habitat for diving species like redhead and ruddy duck. The plants robust structure and dense growth pattern provide optimal cover for the over-water nests of these two species. Ideally, wetlands used for breeding should have relatively stable water levels

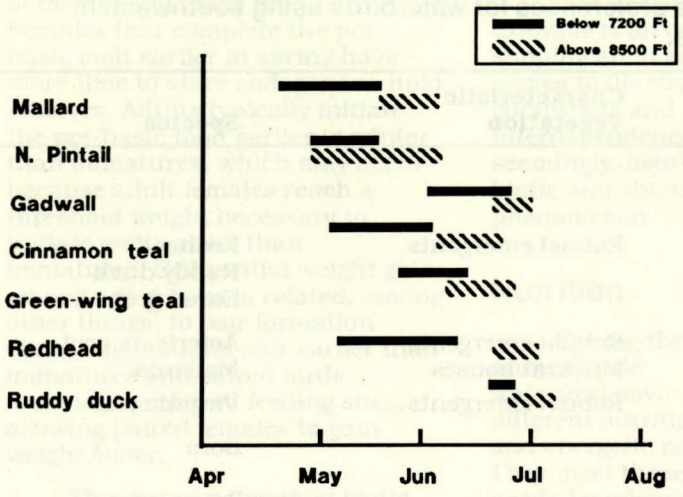



**Figure 14.** Nest initiation dates at different altitudes for seven common nesting duck species using montane wetlands (data from Meyers 1982 and Piest 1982).

during the laying and incubation period. High nest desertion rates are caused by rising water levels which may inundate nests or rapidly drying conditions which may leave nests stranded on dry land. Nest desertion was the only cause of redhead and ruddy duck nest failures in one study on Anderson Mesa, Arizona.

All dabbler species build their nests almost exclusively in upland areas adjacent to wetlands. The most important characteristics for nest site selection are vegetation height and density. Because most dabbler species nest over wide geographic areas, they are typically able to utilize many plant species as nesting cover. Mallard and gadwall typically prefer dense cover at least two-feet high composed of a mixture of grasses and broad leaved species such as sweet clover. In Arizona, important plant species are Arizona fescue, western wheatgrass, pine dropseed, mountain muhly, and thistle. When preferred nesting cover is lacking, dabblers select sites at the base of rabbit brush, juniper, and pine trees. Cinnamon teal also prefer dense vegetation and will be found in the same habitats as mallards and gadwall, but they make heavier use of shorter vegetation such as salt grass and stands of spike rush. In contrast, pintails prefer habitats with little or no vegetation and often select nest sites on bare soil. Females rely on their cryptic plumage to protect them against predation. All species may utilize nesting islands within wetlands but Canada geese in particular prefer them.

In high altitude wetlands with short growing seasons, many waterfowl species begin to nest before new vegetation growth begins. Therefore, the height and density of residual vegetation in spring is very important when choosing a nest site. Studies on prairie wetlands have found higher nesting densities, nest success, and duckling survival in areas ungrazed the previous year for mallards and gadwall. The impact of reduced vegetation on teal or pintail that prefer shorter nest cover may not be as severe.

Nest placement within and around a wetland complex is determined by variable nest cover requirements among waterfowl species and differences in nest placement from the waters' edge. Divers are restricted to semipermanent wetlands, because seasonal wetlands cannot support the robust emergent growth these species prefer whereas dabbler species use both semipermanent and seasonal wetlands (Table 15). Most dabbler species locate their nests within 100 yards of water, cinnamon teal often within 40 yards, whereas pintail commonly locate nests further than 100 yards (Fig. 15).

Both divers and dabblers are particularly vulnerable to disturbance during the nesting period. Besides the effect drastic water level changes can have on divers, grazing by elk or livestock can adversely affect habitat conditions for all species. Grazing activity can directly destroy nests by trampling, increase nest desertion, and cause increased predation by decreasing nesting cover.

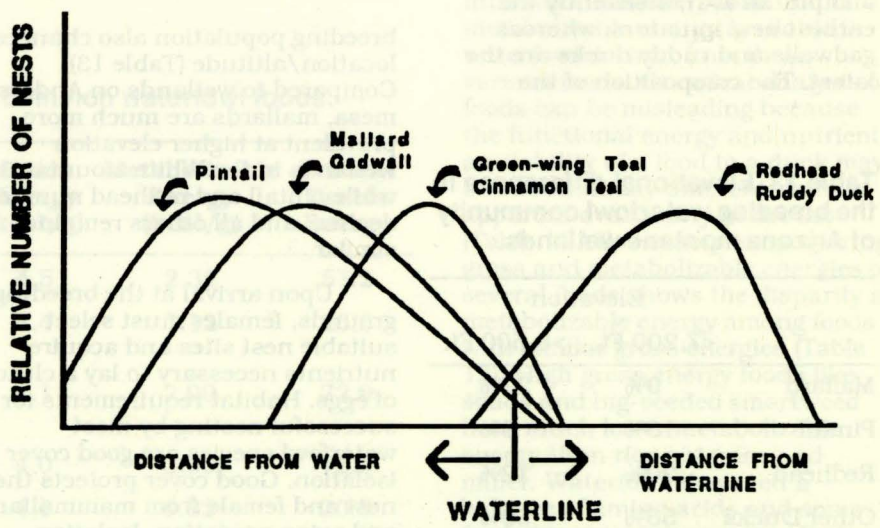



**Figure 15.** Nest location in relation to distance from wetland edge for common montane nesting waterfowl.

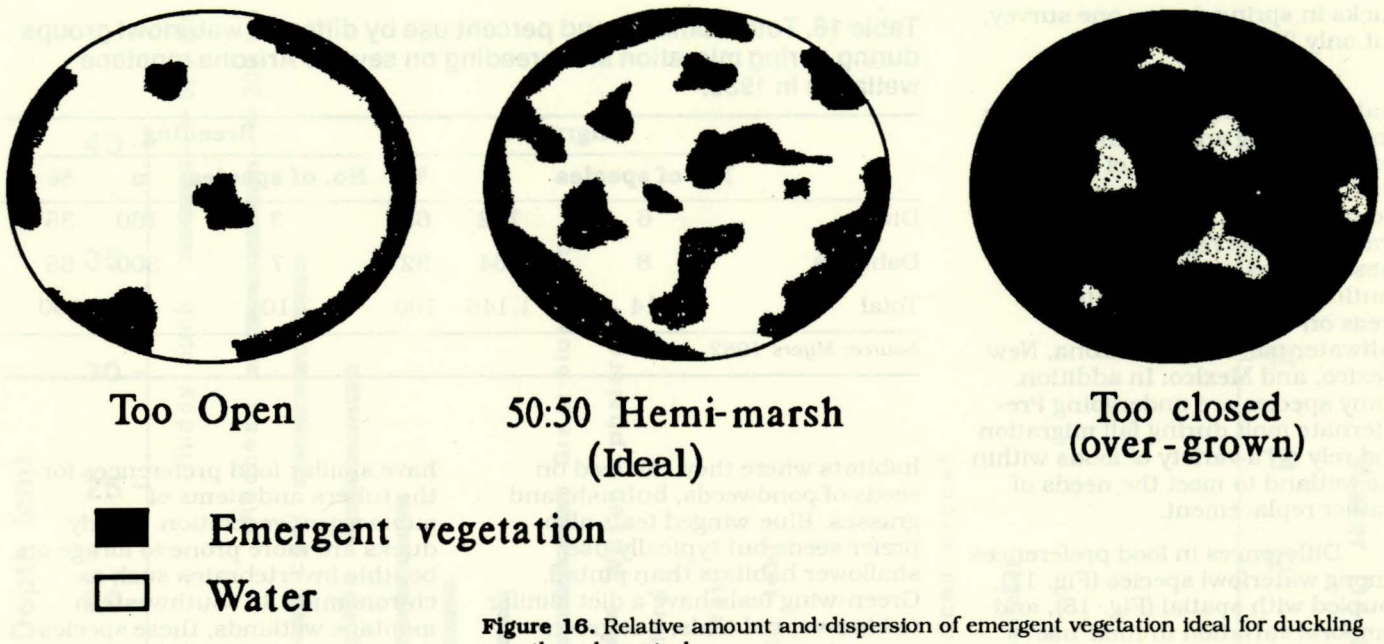



**Figure 16.** Relative amount and dispersion of emergent vegetation ideal for duckling growth and survival.

## Brood Rearing

Although vegetation characteristics of upland habitats around wetlands are important for attracting nesting ducks, the suitability of a wetland or a complex of wetlands as brood habitat is also a critical factor. The two main habitat needs during the brood rearing period are cover and readily available protein resources. Research on prairie wetlands has shown that a ratio of open water to emergent vegetation of 50:50 is optimal for broods. Furthermore, the vegetation should be distributed in small clumps throughout the wetland not just along the edge (Fig. 16). Stands of spike rush and bulrush often form an excellent interspersion of vegetation and water.

Young ducklings forage primarily on invertebrates during the first weeks of development. Dense stands of submerged aquatics like musk grass, waterweed, water milfoil, and water smartweed provide excellent substrate for invertebrate populations. Development of ducklings to fledging stage takes from 46-73 days depending on the species and latitude. As the ducklings develop, their diet begins to reflect adult preferences.

## Non-breeding

North American waterfowl species spend as much as eight months away from their breeding grounds. The quality of these habitats directly affects many key parameters which determine annual waterfowl populations. For example, hunting vulnerability is directly related to the quality of fall and early winter habitat for mallards, pintails, and canvasbacks. As we have already seen, processes started in fall and winter directly affect subsequent spring recruitment. Unfortunately, non-breeding habitats have been lost at a disproportionately high rate to breeding habitats, further increasing the importance of remaining wetland habitats.

## Migrating

Although some montane wetlands support relatively high densities of nesting waterfowl, they are used by a larger number of species and in greater numbers during migration (Table 16). This difference in use is accompanied by a shift in the dominate guilds of ducks using the wetlands. Diving ducks dominate these systems in spring, whereas dabblers predominate in summer (Table 16). Two species, the ring-necked duck and bufflehead comprised 41% of all

**Table 15. Percent use of two breeding waterfowl guilds in two types of Arizona montane wetlands.**

| | Wetland Type | |
|---|---|---|
| **Waterfowl Guild** | **Seasonal** | **Semi-permanent** |
| Divers | 0% | 100% |
| Dabblers | 38% | 62% |

*Source: Myers 1982*

ducks in spring during one survey, but only 3% in summer.

Fall band returns indicate that the majority of the birds come from breeding areas in the intermountain regions of Utah and Idaho, and western Wyoming, Montana, and Colorado, not the prairie pothole region. During fall these species need energy to continue migration to wintering areas on the freshwater and saltwater marshes of Arizona, New Mexico, and Mexico. In addition, many species are undergoing Pre-alternate molt during fall migration and rely on a variety of foods within the wetland to meet the needs of feather replacement.

Differences in food preferences among waterfowl species (Fig. 17), coupled with spatial (Fig. 18), and temporal variation in their use allow many species of waterfowl to utilize a single wetland complex. The first migrants in fall are typically blue-winged teal, pintail, and American wigeon. Wigeon, like gadwall prefer leaves and stems of submerged aquatics like pondweeds and milfoil. Unlike gadwalls however, wigeons often graze on the leaves and stems of vegetation in surrounding uplands. Pintails prefer open habitats where they can feed on seeds of pondweeds, bulrush, and grasses. Blue-winged teals also prefer seeds but typically use shallower habitats than pintail. Green-wing teals have a diet similar to blue-winged teals, but green-wings do not arrive in fall until after most blue-wings have departed. Mallards are omnivorous, but show seasonal preferences for certain foods. Northern shovelers have a diet unique among waterfowl. They filter feed for phytoplankton, zooplankton, and macroinvertebrates in deep or shallow waters, often devoid of submerged macrophytes. Their wide bill and elongated lamellae are special adaptations for this purpose.

Canvasbacks, ring-necked ducks, and redheads all have similar food preferences for the tubers and stems of submergent vegetation. Ruddy ducks are more prone to forage on benthic invertebrates such as chironomids. In southwestern montane wetlands, these species are segregated mostly by timing of use. Ring-necks utilize southwestern montane wetlands primarily as migrational areas, whereas redheads and ruddy ducks are common breeding species and canvasbacks are uncommon during all seasons. Buffleheads differ from other diver species using montane wetlands because of their preference for animal matter. Up to 70% of a buffleheads diet is

**Table 16. Total numbers and percent use by different waterfowl groups during spring migration and breeding on several Arizona montane wetlands in 1980.**

| | Migration | | | Breeding | | |
|---|---|---|---|---|---|---|
| | No. of species | n | % | No. of species | n | % |
| Divers | 6 | 782 | 68 | 3 | 160 | 35 |
| Dabblers | 8 | 364 | 32 | 7 | 300 | 65 |
| Total | 14 | 1,146 | 100 | 10 | 460 | 100 |

*Source: Myers 1982*

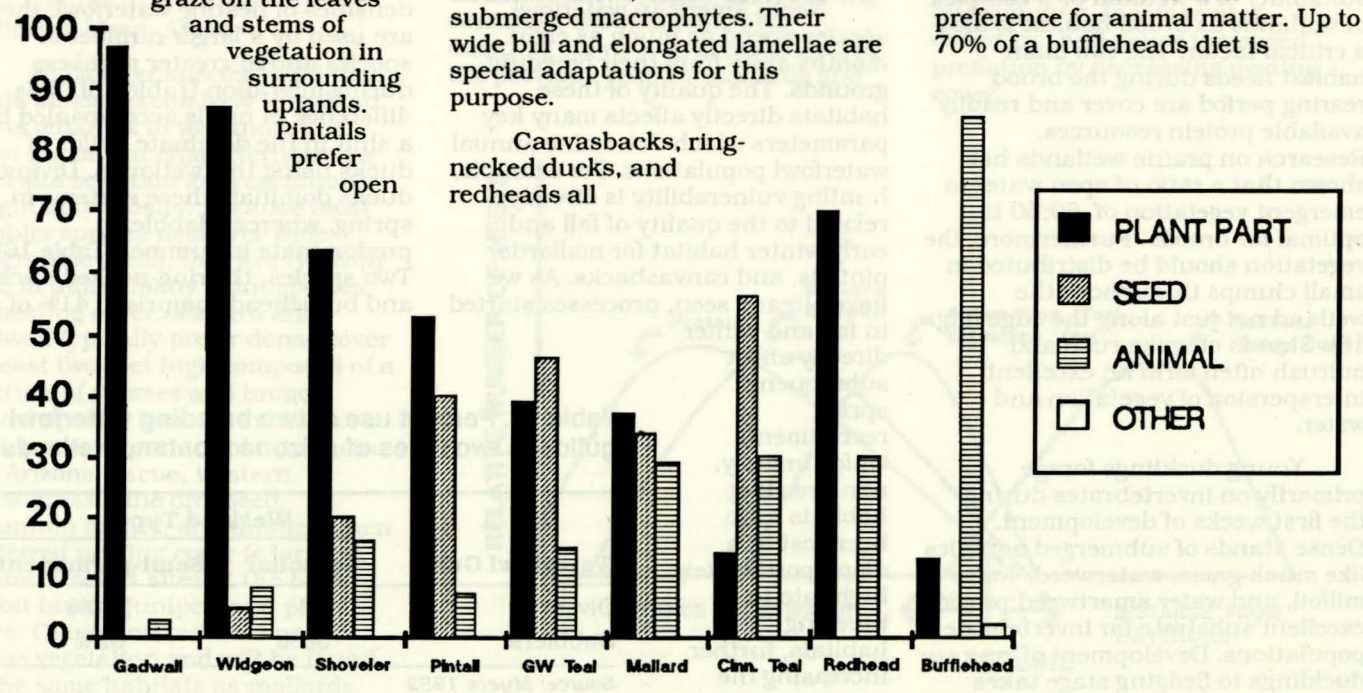



**Figure 17.** Variation in the diets of nine species of ducks during non-breeding seasons in Arizona.

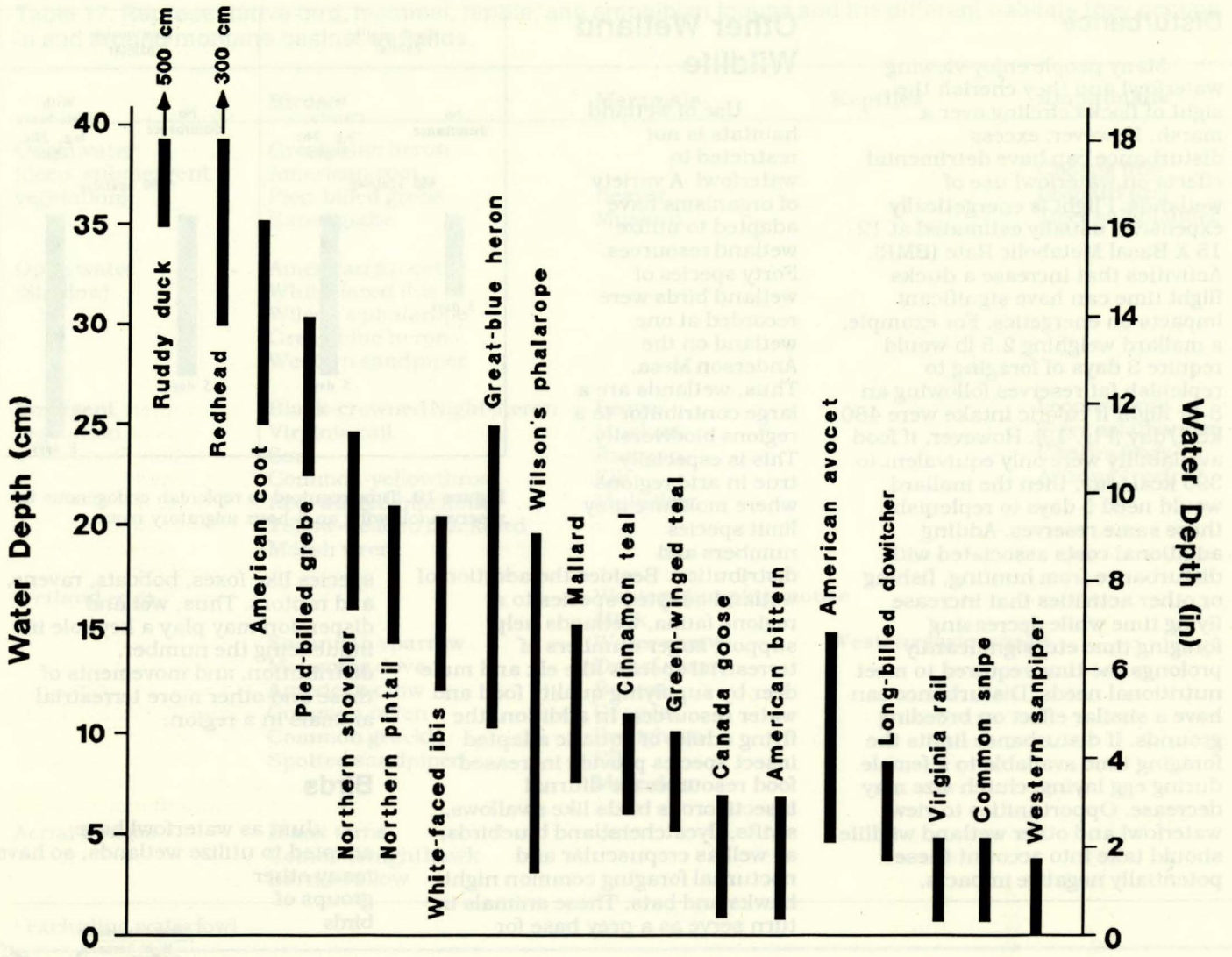



**Figure 18.** Preferred foraging depths for waterbirds using southwestern montane wetlands.

macroinvertebrates taken both from the substrate and water column.

In spring, snow melt fills the smaller ephemeral wetlands that were dry in fall, making a wide range of wetland types and food resources available. These newly flooded wetlands support macroinvertebrate communities specially adapted to these dynamic vernal flooding regimes. Invertebrates provide an excellent source of protein which aids feather growth during Pre-basic molt and egg formation during laying. Mallards, pintails, and teals especially, make use of these resources. Newly sprouting spike rush and grasses provide food for geese, gadwalls, and wigeon. In larger wetlands that retain water all winter, some invertebrate species have life cycles that allow continued growth and reproduction beneath the frozen surface. Spring thaw makes these invertebrates available. The flush of nutrients added to wetlands by the spring runoff and warming water temperatures provide ideal growing conditions for plankton, algae, macroinvertebrates, and submerged aquatic plants used by shovelers and diving ducks.

## Wintering

Because of elevation, most montane wetlands are frozen during winter, thus very few waterfowl winter in the region. At lower elevations in the region some water remains open in certain years, thus a few mallards may appear during winter.

## Disturbance

Many people enjoy viewing waterfowl and they cherish the sight of flocks circling over a marsh. However, excess disturbance can have detrimental effects on waterfowl use of wetlands. Flight is energetically expensive, usually estimated at 12-15 X Basal Metabolic Rate (BMR). Activities that increase a ducks flight time can have significant impacts on energetics. For example, a mallard weighing 2.5 lb would require 3 days of foraging to replenish fat reserves following an 8-hr flight if caloric intake were 480 kcal/day (Fig. 19). However, if food availability were only equivalent to 390 kcal/day, then the mallard would need 5 days to replenish those same reserves. Adding additional costs associated with disturbance from hunting, fishing or other activities that increase flying time while decreasing foraging time etc. significantly prolongs the time required to meet nutritional needs. Disturbance can have a similar effect on breeding grounds. If disturbance limits the foraging time available to a female during egg laying, clutch size may decrease. Opportunities to view waterfowl and other wetland wildlife should take into account these potentially negative impacts.

## Other Wetland Wildlife

Use of wetland habitats is not restricted to waterfowl. A variety of organisms have adapted to utilize wetland resources. Forty species of wetland birds were recorded at one wetland on the Anderson Mesa. Thus, wetlands are a large contributor to a regions biodiversity. This is especially true in arid regions where moisture may limit species numbers and distribution. Besides the addition of wetland adapted species to a regions fauna, wetlands help support larger numbers of terrestrial species like elk and mule deer by supplying quality food and water resources. In addition, the flying adults of aquatic adapted insect species provide increased food resources for diurnal insectivorous birds like swallows, swifts, flycatchers, and bluebirds, as well as crepuscular and nocturnal foraging common nighthawks and bats. These animals in turn serve as a prey base for species like foxes, bobcats, ravens, and raptors. Thus, wetland dispersion may play a key role in influencing the number, distribution, and movements of these and other more terrestrial animals in a region.

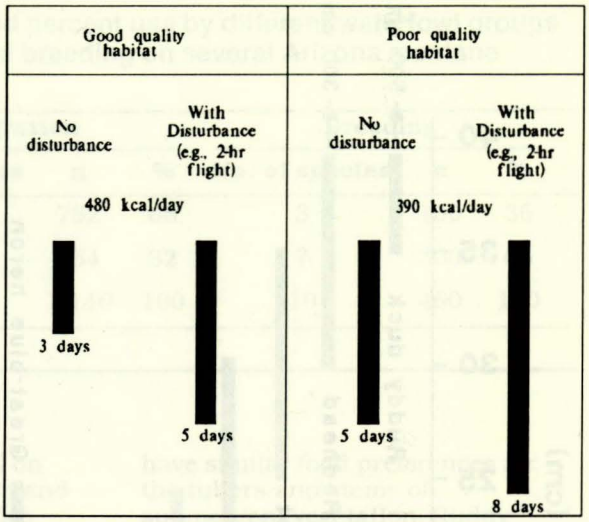



**Figure 19.** Time required to replenish endogenous fat reserves following an 8-hour migratory move.

## Birds

Just as waterfowl have adapted to utilize wetlands, so have many other groups of birds

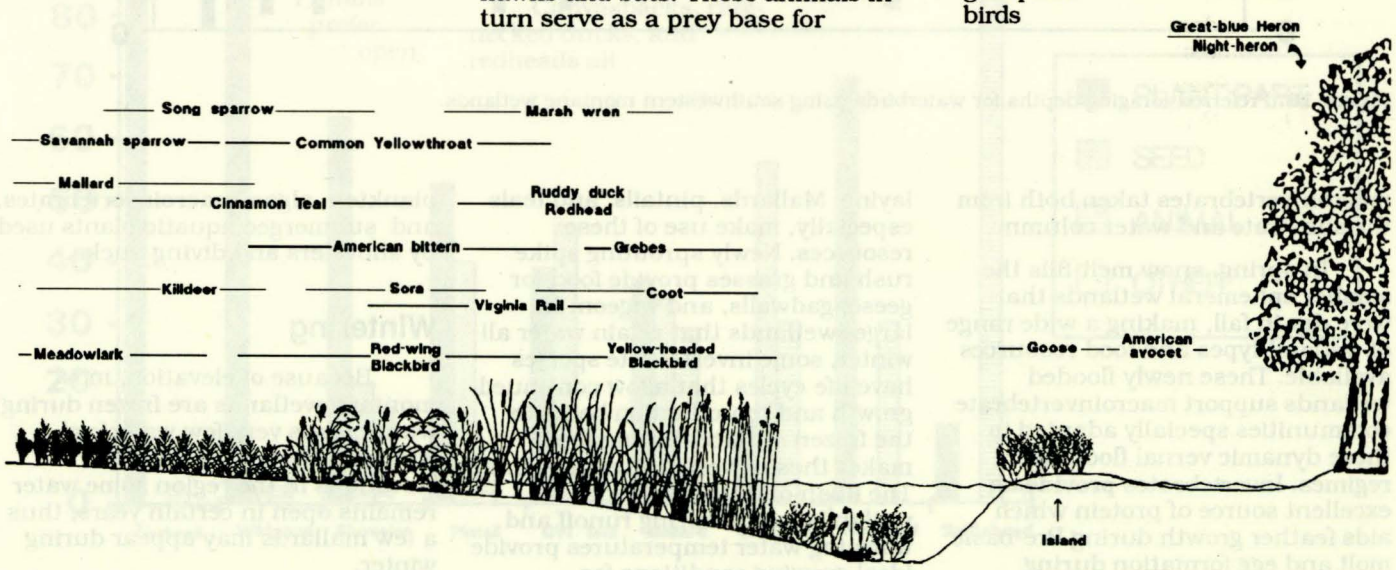



**Figure 20.** Nest site placement by marsh nesting birds showing segregation by habitat and flooding depth.

**Table 17. Representative bird, mammal, reptile, and amphibian faunas and the different habitats they occupy in and around montane basinal wetlands.**

| | Birds [1] | Mammals | Reptiles | Amphibians |
|---|---|---|---|---|
| Open water (deep, submergent vegetation) | Great-blue heron<br>American coot<br>Pied-billed grebe<br>Eared grebe | <br><br>Beaver<br>Muskrat | | Chorus frog<br>Leopard frog<br>Tiger salamander |
| Open water (Shallow) | American avocet<br>White-faced ibis<br>Wilson's phalarope<br>Great-blue heron<br>Western sandpiper | | | |
| Emergent vegetation | Black-crowned Night-heron<br>Virginia rail<br>Sora<br>Common-yellowthroat<br>Red-winged blackbird<br>Yellow-headed blackbird<br>Marsh wren | Beaver<br>Muskrat<br>Raccoon<br>Elk<br>Mule deer | | Leopard frog<br>Tiger salamander<br>Chorus frogs<br>Arizona treefrog |
| Wetland edge | <br><br>Savannah sparrow<br>Mourning dove<br>American crow<br>Common raven<br>Common grackle<br>Spotted sandpiper | Western jumping mouse<br>Mink<br>Water shrew<br>Dwarf shrew<br>Bobcat<br>Gray fox<br>Pronghorn<br>Elk<br>Mule deer | <br><br>Western gartersnake | |
| Aerial forages | Black terns<br>Common nighthawk<br>Barn swallow | Bats | | |

[1] excluding waterfowl

(Table 17). Different vegetation zones meet the breeding needs of different species (Fig. 20). Wetlands with good stands of bulrush and cattail support nesting, eared grebes, pied-billed grebes, american coots, red-winged blackbirds, yellow-headed blackbirds, and common yellowthroats. Breeding soras and Virginia rails also use the robust vegetation for breeding, but prefer shallow wetlands with good stands of seed producing moist-soil plants and cover created by spike rush and bulrush during migration (Table 16).

Interspecific competition among these species is reduced by spatial segregation and different foraging patterns. Both marsh nesting blackbirds and the common yellowthroat place their nests and forage above the ground. Because of their smaller size, yellowthroats can effectively forage among the dense bulrush stems, whereas blackbirds feed more in the upper canopy and may catch insects flying above the vegetation. Rails, grebes, and coots have nests on the ground or water surface. Grebes and coots place nests over much deeper water than rails which may also nest on dry ground (Table 16). Rails forage on uplands or shallowly flooded soils among vegetation, whereas grebes and coots feed in open water and on fish or submerged vegetation respectively.

Open, shallow areas are occupied by nesting American avocets and black-necked stilts, and migrating western sandpipers and Wilson's phalaropes. Avocets, stilts, and phalaropes forage in the water column for invertebrates like fairy shrimp, whereas western sandpipers probe the mud for midge larvae and spotted sandpipers follow the shoreline while gleaning insects. Because of their ephemeral nature, most shallow wetland basins lack

fish communities. The lack of competition from fish for invertebrates results in high densities and excellent food resources for migrant waterbirds. These shallow wetlands were historically important to migrating sandhill cranes as they passed to and from wintering grounds in southeastern Arizona and Mexico. However, wetland degradation and disturbance has eliminated this species from the region.

Smaller bird species attract raptors which exploit them as food. Merlins and peregrine falcons feed on shorebirds with peregrines occasionally taking teal. During migration northern harriers and bald eagles scavenge waterfowl carcasses and hunt for rodents and fish, respectively. Ospreys frequent wetlands with fish, their primary food source. Other birds that breed in the surrounding uplands but utilize wetlands when foraging include, western kingbird, barn swallow, savannah sparrow, common nighthawk, and morning dove.

## Mammals

Except for muskrats and beaver, which are found primarily in wetlands near permanent water, few mammals are restricted to using wetlands for all aspects of their annual cycle. Because they rely on emergent vegetation as their primary food source, muskrats play a major role in altering wetland structure and vegetation patterns. Beaver are found in association with riparian habitats where their dam construction forms pools that are used by mallards in spring. A variety of terrestrial mammals exploit seasonally available food resources (Table 17). In particular, elk and mule deer frequently graze on emergent and submergent vegetation while raccoon and mink forage on a variety of foods in and around wetlands, including bird eggs, young birds, herps, and fish.

## Fish

The isolated nature of most montane wetland basins and their periodic drying cycles precludes the presence of a diverse fish community. Where wetland basins are adjacent to streams, the young of minnows and suckers are seasonally present. Several of the larger palustrine wetlands and reservoirs are stocked with several species of salmonids, eastern centrachids like the green sunfish and golden shiner, and predators such as northern pike. Pike in particular may exert heavy predation pressure on waterfowl ducklings.

## Reptiles and Amphibians

Reptile and amphibian diversity is restricted by the same factors as fish, plus the extremely cold conditions that persist throughout winter. Western garter snakes, leopard frogs, and tiger salamanders are the only common representatives from this group of organisms (Table 17).

# An Approach To Wetland Management

Decisions relating to wetland management will be effective and have long-term value only if they are based on good information about a variety of factors on both a regional or ecosystem level and at the level of an individual wetland. At the ecosystem level important information about wetland status, values, and functions includes:

1) What is the distribution of the remaining wetlands in relation to their type, size, and function?

2) Is the current regional wetland condition greatly altered from historical natural conditions?

3) What plant and animal species historically used the regions wetlands?

4) What habitats must be provided for target species?

5) What life history events do these species undergo while using montane wetlands?

6) What competing use factors must we consider and include in any management plan (e.g., hunting, fishing, birding, camping, grazing)?

Only by consciously considering wetlands on such a regional scale with the understanding that each isolated basin is a part in the whole regional wetland picture can a manager be assured of providing a functioning wetland ecosystem. Bypassing this process and immediately concentrating on individual wetland basins usually results in the failure to provide the wide range of habitats necessary to support the full range of wetland species using a wetland or wetland complex annually. Answering these questions will provide a clear picture of current wetland ecosystem resources and values and serve as a starting point for further decisions. In addition, comparing historic use patterns and abundance with current conditions can provide some guidance in outlining attainable goals for a management plan.

The goals of any management plan should be reasonable and reflect the seasonal importance of an area to the target species. Efforts to improve waterfowl use during one part of the annual life cycle should not compromise the value of a regions wetlands during other times of the year or preclude use by other species. Similarly, if seasonal target population goals are set for a region they should be based on population densities recorded during historic times in the region. Managers trying to set goals by comparing montane wetlands with naturally more productive prairie wetlands would set unrealistically high goals. Even if these goals were theoretically attainable, the huge monetary and personnel commitment required would make such goals impractical.

**Figure 21.** Information on a regional level that is helpful for setting montane management goals.

## The Wetland Complex

Analysis of wetland distribution and seasonal bird use within the region may point to the existence of natural wetland complexes. Typically, a wetland complex refers to a group of wetlands that vary in size, shape, type, hydrology, and function. Individually they are important to different species at different times of the year; but together they provide habitat and resources for all species throughout the year. Ideally, all wetlands that form a complex are located within an imaginary circle with a 10 mile radius and represent a group that should be considered as a composite when making management decisions (Fig. 13). Classic examples of wetland complexes include a group of prairie wetland basins ranging from Types I-VII, or a river and it's associated flood plain lakes.

A montane wetland complex may consist of many ephemeral basins that provide food and loafing areas for migrating and pre-breeding birds (Table 8). Small Type III marshes provide early food and isolated pair water for ducks. In some years they will support breeding ducks, coots, rails, and grebes. Small ponds created by beaver activity along streams are excellent for pair and breeding water for mallards. A smaller number of large Type III and Type IV basins provide nesting habitat for diving ducks, and excellent brood habitat for most wetland nesting waterbirds. They also are used by foraging white-faced ibis, great-blue herons, and black-crowned night-herons. Because these basins often remain

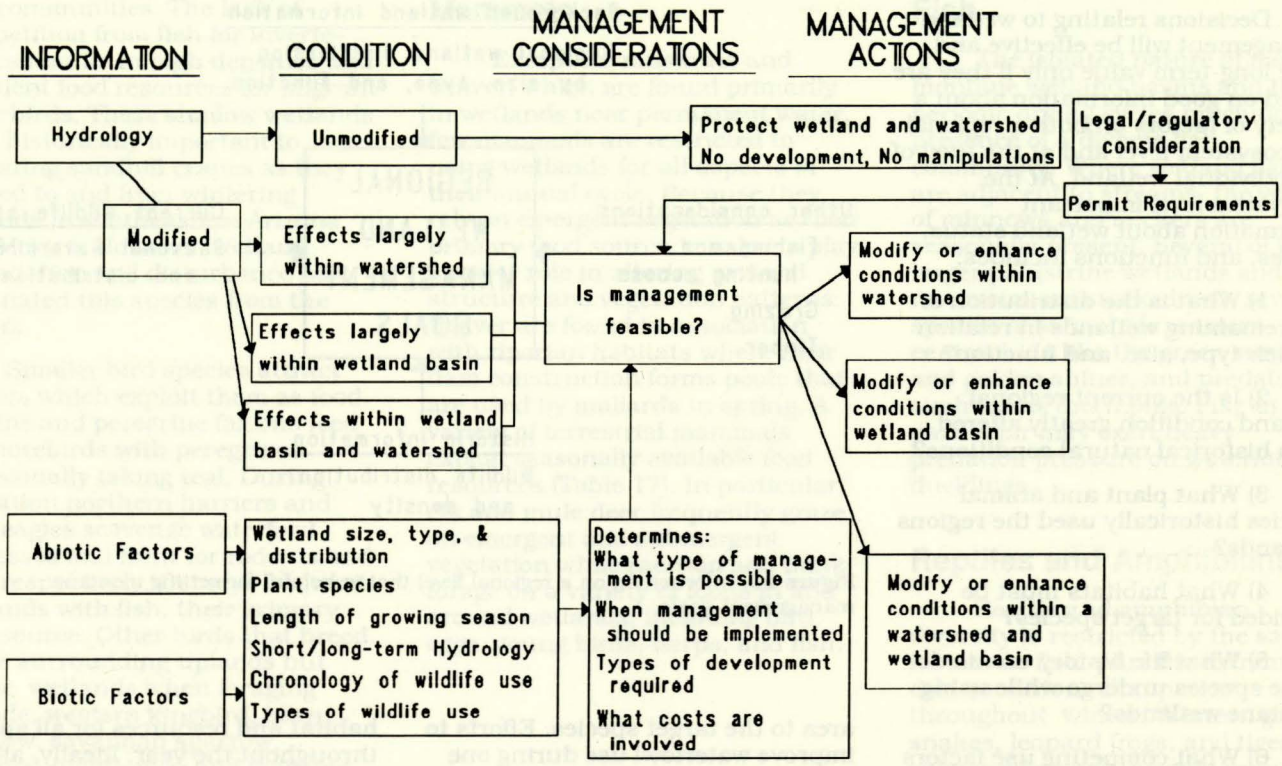



**Figure 22.** Decisions and information required for evaluating the potential and need for management of a wetland.

flooded through fall, they support molting birds in late summer and migrating birds in fall. Man-made reservoirs may provide some food resources for migrating divers and grebes in spring and fall, but they are usually too deep and open to be of value as nesting habitats. However, they do serve as good roosting areas safe from predators with waterfowl flying to other nearby wetlands to feed. A variety of piscivorous species like common mergansers, cormorants, herons, grebes, kingfishers, bald eagles, and osprey will utilize any wetland with fish populations.

Montane wetlands tend to be more widely dispersed, thus identifiable natural complexes like the example above may not predominate. Despite this fact, the concept of managing for complexes of different wetland types is still useful. It provides a way of thinking about the role different wetland types play and the importance of variety to a successful wetland ecosystem.

## Individual Basins

The final step in this hierarchical process involves making specific decisions about management of individual wetland basins to meet regional or complex objectives. Relevant information that assists in this determination includes (Fig. 21):

### Hydrology

1) Has the wetland hydrological regime been modified by man's activities?

2) If the hydrology has been modified, what caused the changes?

3) What factors outside the wetland influence the hydrological regime?

### Biotic Factors

1) What types and numbers of wetland wildlife currently occur on this wetland?

2) What is the annual chronology of use for each species?

3) What life history events do these species undergo while using this wetland?

4) What plants commonly occur within the wetland?

### Abiotic Factors

1) What is the length of the growing season?

2) What is the precipitation cycle, annual and long-term? What variation should be expected within and among years?

3) What soil types are present?

4) How deep is the water table? Are there substantial seasonal variations in water table level?

## Legal/Regulatory

1) Will management impact adjacent land owners?

2) What regulations apply to the wetland?

3) What permits are required and from what agencies?

Once this information gathering and planning process has been completed, the type and intensity of management that would produce the best results can be identified (Fig. 22). These decisions are particularly critical in regions that have widely scattered wetlands of small size because each development impacts only a small area and the time required to visit each wetland to conduct management actions is limited.

Deciding whether a specific wetland will receive active management depends on whether the wetland has optimum value in its current condition or whether modifications changed the wetland in such a way that its functions and values have been compromised (Fig. 22). In some cases, protecting a wetland from additional modifications may be the most effective and valuable approach. Protection should always be considered as an option that falls within the category of good management despite the fact that no development or manipulations are planned for the site. This decision is particularly important because naturally functioning wetlands can not be improved upon by man and wetland development and management is expensive, causes additional modifications to wetland functions and values, and often requires an extensive man-power commitment to monitor and sustain habitat values.

If wetland values have been compromised because of modified hydrology then some hands-on action is justified. If intensive management is warranted then a decision must be made to determine whether management actions should focus on the wetland basin itself or on the watershed surrounding the wetland (Fig. 22). In montane wetlands where basins are often small or ephemeral and widely distributed, management actions to a watershed often produce the best results both biologically and economically. Examples of this type of management include decisions on location of roads; size, type and location of culverts; grazing; mowing; digging/blasting; logging; and recreational activities (Table 18).

Some management action might be taken within the wetland basin proper. This includes decisions such as developing levees; changing the location, elevation, type, or size of water control structures; blasting or digging openings; making islands; establishing sanctuaries or controlling public use; controlling vegetation with chemical or mechanical means; and manipulating water levels (Table 18).

**Table 18. Management options in montane wetlands.**

| Management Goal | Management Action |
|---|---|
| Optimize brood habitat | 50/50 Cover by Grazing, Burning, Mowing |
| | Create sanctuaries where needed |
| | Insure or increase invertebrate foods |
| Increase nesting densities | Increase residual vegetation |
| | Construct islands |
| | Artificial nest structures |
| | Change grazing patterns |
| Provide pair water | Protect ephemeral wetlands |
| | Maintain temporary wetlands |
| | Decrease human disturbance |
| Provide food resources | Maintain water quality, hydrology |
| | Encourage submergent vegetation |
| | Controlled burning, grazing |
| | Increase surface area flooding |
| | Maintain shallow foraging depths |

## Management Considerations Within A Watershed

### Grazing

Areas adjacent to wetlands and areas within wetlands support higher forage production because higher water tables or flooding promote better plant growth. Furthermore, the nutritional value of this forage might be higher than forage in the surrounding uplands. These conditions tend to attract high densities of grazers within and surrounding wetlands. Impacts to wetlands can be particularly severe in arid montane areas where drinking water and upland forage is scarce. Understanding the potential impacts is the best way to avoid these problems.

Grazing programs influence wetland values in at least three distinct but important ways. The timing and intensity of grazing controls residual vegetation characteristics. Given the importance of residual vegetation to nesting waterfowl, grazing impacts should be controlled within and around and within important breeding wetlands. Because each nesting species has a somewhat different cover requirement (see Wetland Wildlife section), a mix of residual vegetation surrounding and within a breeding wetland as well as the vegetation from sparse to more robust and dense would provide a mix of cover suitable for most nesting ducks. If grazing coincides with laying and incubation periods, livestock may reduce nest success by trampling, increasing disturbance that causes abandonment, or increasing predation rates by reducing protective cover.

Grazing also impacts the vegetation within the watershed by influencing the volume and quality of runoff water. Heavily grazed systems that lack residual cover often have higher more rapid runoff that carries more sediments. Rapid water inflows might flood the nests of marsh nesting species. Increased sedimentation reduces the light penetration into the wetland water column influencing submerged plant germination and growth. Heavy grazing also results in a reduction of plant diversity, often favoring species with little wildlife value. Finally, soils in high use areas will suffer from trampling. Soil compaction can reach a point where it reduces or prevents plant germination, even after grazing is stopped.

Many of the waterbirds associated with montane wetlands in Arizona nest in robust vegetation within the wetland basin. For most species ideal nest habitat provides structure for nest attachment and concealment from predators. For this reason fencing is an important tool to protect the desired structural features of vegetation within the basin. Because most waterfowl nesting is within 100 yards of the wetland basin, fencing all or part of this area surrounding a wetland basin provides better control of the structure of residual vegetation. The most critical zones for protection are those within the wetland and the more robust vegetation immediately adjacent to the zone of flooding. Fencing within the wetland proper is discouraged because fences are difficult to maintain in the soft substrates, ice may cause damage during winter and during the spring break-up and livestock are more likely to damage fences in the vicinity of lush wetland vegetation. Water for livestock can be provided by tanks away from the wetland basin or below dams or levees of man-made wetlands.

However, used correctly livestock grazing can be a useful management tool. Much like fire, livestock have been used to effectively maintain early seral stages in vegetation communities around and within a wetland which benefit upland nesting species. Likewise, grazing can breakup dense stands of vegetation within the wetland basin to provide loafing areas, to promote better foraging areas or to improve interspersion for nesting. Within a wetland, cattle can open up monotypic stands of robust emergents to achieve the desired 50:50 ratio of water and cover. Contrary to heavy or moderate grazing pressure, light grazing can have positive impacts on plant species diversity. The definition of heavy, moderate, and light grazing pressure varies depending on the ecosystem being discussed. Experiments that monitor the plant response at different stocking rates will help to create locally relevant definitions. In general, light grazing pressure should not adversely impact ecosystem function or value. Heavy grazing pressure for short periods may also have benefits; however, heavy grazing pressure for long periods severely reduces plant and animal species diversity in an area.

The value of grazed natural wetlands or man-made stock tanks can be improved by controlling the timing and minimizing the grazing pressure. Assuring the presence of shoreline vegetation will reduce sediment loading into wetlands, reduce the impact of wind on evaporation rates, and increase the security of the wetland to nesting waterbirds. Partial exclosures that restrict cattle access may be one way of achieving this result. Not grazing when waterfowl are incubating will reduce nest failures. Finally, reduce grazing pressure to maintain residual vegetation for next spring will encourage waterfowl nesting.

## Fire

Periodic fires are an important part in the function of natural wetland ecosystems and it may be constructively used in management situations. Fire is effective for setting back succession, eliminating shrub and tree encroachment on a wetland and encouraging seasonal grasses and forbes which are better for nesting waterfowl. Fire can also be effective to control specific undesirable wetland plants or to open up dense monotypic stands of robust emergents like hardstem bulrush and spike rush that can develop under stable water regimes. Burns eliminate excess detritus; release nutrients back into the soil; and increase plant germination, growth, and content on both uplands and in wetlands. Shoots of hardstem bulrush, cattail, salt grass, and several sedges have higher protein content after fire, increasing their nutritional value to waterfowl and invertebrates. Geese in particular favor the newly developing shoots of emergents after fire.

The timing of a burn will depend on the result a manager wishes to achieve. If the goal is to provide early growth grasses for browse to pre-nesting Canada geese, an early spring burn will achieve the best results. Unfortunately, this same burn would eliminate the upland cover around a wetland and thus reduce the available nesting habitat for

ducks. In general, if controlling a specific plant species is the goal, burns should be planned when the species is biologically most susceptible. An early spring burn to control hardstem bulrush may not be effective for controlling this perennial. During late summer when water levels are lower, root system carbohydrate stores also are at their lowest. Fire during this period will prevent extensive regrowth because fall is approaching.

## Roads

The location, number, and type of roads have the potential to impact the hydrology of a wetland. Roads have impacts on wetlands whether they are upstream or downstream from the wetland basin. Impacts are partly determined by the location, type, and size of culverts. If new roads are developed they should circumvent wetland basins of any type because they may cause drainage of basins or stabilize the water at a higher level.

Established roads should be evaluated for their potential to impact wetlands. Could a wetland be restored or enhanced in some way by changing the location or elevation of the road? Careful consideration should be given to new road construction. Circumventing wetlands basins in a way that preserves the natural hydrological regime is of paramount importance.

## Timber Harvest

Runoff with the associated sediments may change in relation to the time, location, or extent of a timber harvest in conjunction with the presence or location of roads and/or grazing programs. Thus when important wetlands are involved, careful consideration should be given to minimizing water quality deterioration in the basin. Harvest might be important to improve the vegetation structure, composition, or habitat type for a target group of wetland associated wildlife; however, activities associated with harvest might create disturbance during a critical period in the annual cycle of the same species. Careful timing of harvest activities may eliminate this conflict. In general, it is a good policy to avoid the compounding negative impacts from activities like grazing, timber harvest, recreation, and road location on a wetland designated to have wildlife value.

## Seeding and Planting

A habitat evaluation of montane areas on the Apache-Sitgreaves NFs concluded a lack of suitable nesting habitat limited waterfowl nesting densities. Seeding grasses for cover is one technique for improving upland waterfowl breeding habitat. However, the most likely cause of poor nesting conditions should be determined. Do they result from anthropogenic changes or natural growing conditions? If poor habitat conditions are a result of overgrazing, then seeding additional areas would not solve the problem. In fact, seeding upland habitats might magnify the problem by concentrating livestock around wetlands further.

If grazing is stopped or greatly reduced, seeding might provide a way to increase the density of upland nesting cover. Seeding is particularly valuable and often required for establishing cover on newly created waterfowl nesting islands. Because most ducks initiate nests prior to significant plant growth each season, it is doubtful that planted species would germinate early enough to provide significant cover in spring. The most successful species would be perennials that provide good residual cover the following spring.

# Management Within A Basin

## Regulating Activities

Regulations provide cost effective opportunities to optimize habitat benefits for wetland wildlife. Establishment of sanctuaries on some specified wetlands or parts of wetlands during certain critical time periods often reduces disturbance so that waterbirds can breed, rear young, molt, or acquire foods during migration more successfully. The most effective sanctuaries include a range of habitat types so that many species receive benefits or a single species can meet a wider range of nutritional and cover requirements.

Sanctuaries are particularly important on lakes or wetlands where fishing is an important recreational activity. Good decisions on the timing and location of sanctuaries requires an understanding of the importance of the wetland and the values it provides during the annual cycle. Lakes that provide important roosting habitat during migration might have a sanctuary zone on a portion of the lake before or after a certain date (Fig. 23). Other wetlands might be closed all or in part for longer periods during one breeding season and still others might be closed every year all year.

In addition to protecting against summer disturbance, sanctuaries are particularly important during the hunting season to allow birds undisturbed resting areas. Failure to provide sanctuaries may cause birds to leave an area prematurely, reducing the value of the entire region. Different waterfowl species require different methods of protection. Dabbling ducks will fly many miles between feeding and roosting sites each day. Protection of roosting lakes while allowing hunting on surrounding wetlands is a good strategy to ensure continued bird use in an area. Diving ducks are more sedentary in their habitats often using the same wetland for feeding and roosting. Thus protection requires closing parts or all of key wetlands. This strategy is also best for important dabbler wetlands that are isolated from others, because the birds will be forced to utilize the single wetland for all their activities. Regardless of the season, sanctuaries should be created based

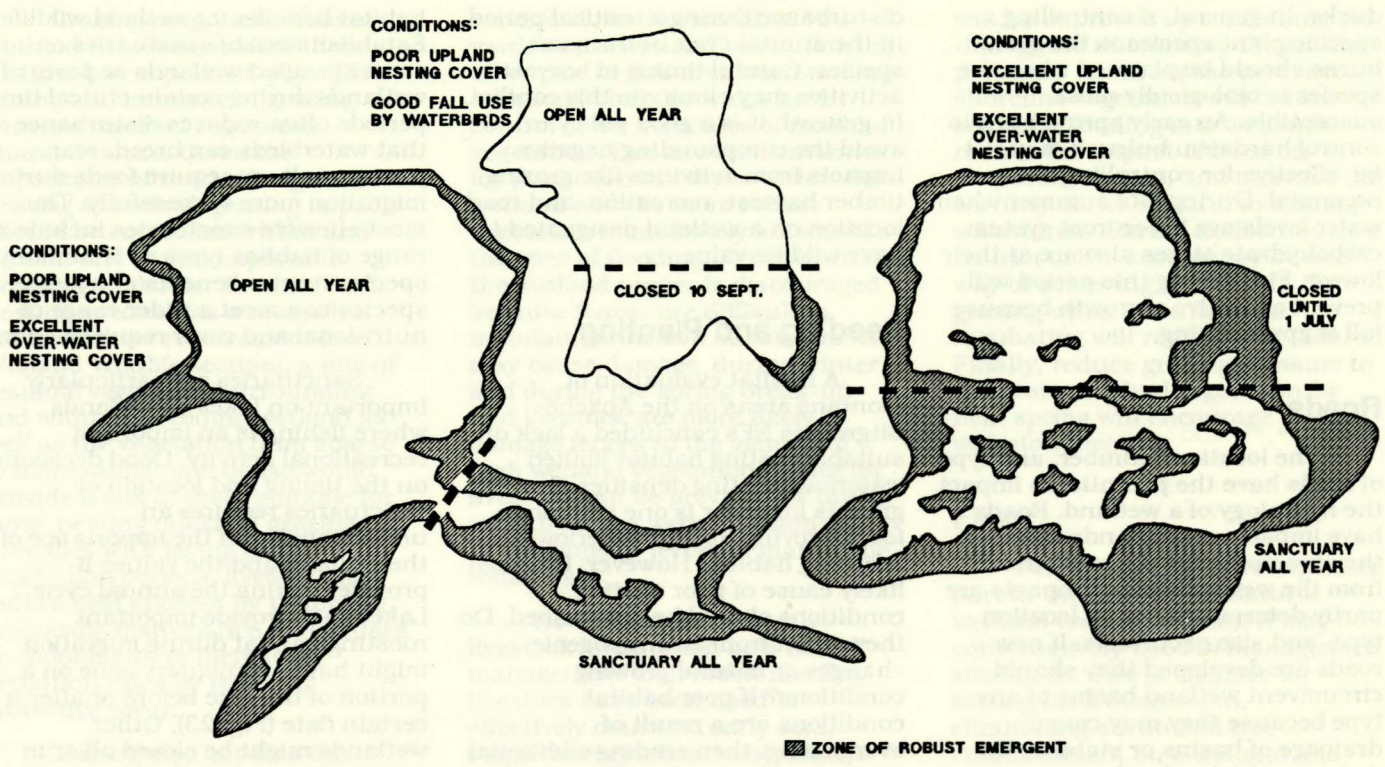



**Figure 23.** Suggested strategies for reducing disturbance on lakes where fishing is permitted.

on historic use and importance of a wetland to regional waterbirds. Using migratory chronology and population data to arrive at any decisions will maximize the benefits of any sanctuary.

## Islands

Waterbirds have responded well to naturally occurring nesting islands on the prairies and in the Arctic. Islands with a good history of successful use are of variable size but they always are free of mammalian predators. Valuable nesting islands are either too small to support indigenous predator populations or they are separated from shore zones by deep water of a considerable width thus preventing predator access. Because islands can support high waterbird nesting densities, artificial nesting island construction is frequently included in wetland management plans. Unfortunately, in most cases there is little consideration given to factors that make naturally occurring islands successful, especially predator access. Nest predation may not be a problem under natural nesting conditions; however, the higher nesting densities that islands support may attract higher predator numbers. In addition, because nests are clumped on islands one predator can destroy all or most of them in one visit.

Islands should always be built under the assumption of potential mammalian predation problems. Because of the small basin size in most montane wetlands, the cost of island construction in relation to benefits may be prohibitive because predators will likely have access to the islands during many seasons. Furthermore, islands should be constructed that match the needs of the target species. For example, islands for shorebirds should have a low profile and very gentle slopes with sparse cover so their semiprecocial young can move about easily and have access to shallow water for foraging (Fig. 24). Ducks can use islands with gentle or relatively steep slopes but they generally require robust vegetation growth on the island. Islands are ideal for geese because their large size and aggressive behavior allow them to defend these small areas from potential predators.

## Artificial Nest Structures

Artificial nesting structures are another way of increasing waterfowl nesting densities. Constructed in the proper way, nesting tubs are popular nest sites for mallards and Canada geese, whereas nest boxes are used by wood ducks, buffleheads, and goldeneyes. As with islands, artificial structures should be placed within the wetland away from the shore, particularly if

mammalian nest predation is a problem. The addition of predator guards is essential to assure nesting success. Nest boxes for cavity nesting species should be placed low enough to facilitate annual maintenance or inspections and spaced wide enough to avoid intraspecific competition or nest interference.

## Changing Basin Morphology

Changing the bottom contour of a wetland is a strategy to increase basin depth and flooding duration or to modify vegetation structure. Current techniques include blasting, digging, or levees. Choosing a strategy depends on the desired result and the hydrology of the basin. All treatments to create openings in stands of robust emergents like bulrush are only temporarily effective. Digging with a tractor or blasting is expensive, time consuming to perform on a regional scale. Initially, constructing levees that permit vegetation control using water manipulations may be more expensive than blasting or digging, but long-term costs will be lower. Unfortunately, without the capability to raise and lower water levels when needed, vegetation control is difficult at best. Given these constraints, it is unlikely that any of these techniques provides a perfect solution for vegetation control in montane wetlands. Grazing, fire, or possibly herbicides likely are the better choices for vegetation manipulations in montane wetlands.

Actions that seek to increase the water holding capacity of a wetland should also seek to maximize the benefits to waterbirds. Blasting often creates deep, steep-sided basins that increase the water holding capacity of a wetland but reduce the functional value of the wetland to wildlife. Plant response is often slow or non-existent in the deeper part of the basin and diversity may be reduced. Open-water habitats are created that have a relatively long life but depth may be too deep for most foraging waterbirds. A major problem with blasting is that the volume of water required to fill the blast hole is so great that the vegetation portion of the wetland is drained earlier in the year or during a longer period of the year (Fig. 25).

Performed correctly, digging is a strategy that allows basins to be deepened while maintaining the gentle slope that favors plant and waterfowl response. It can be particularly valuable for creating

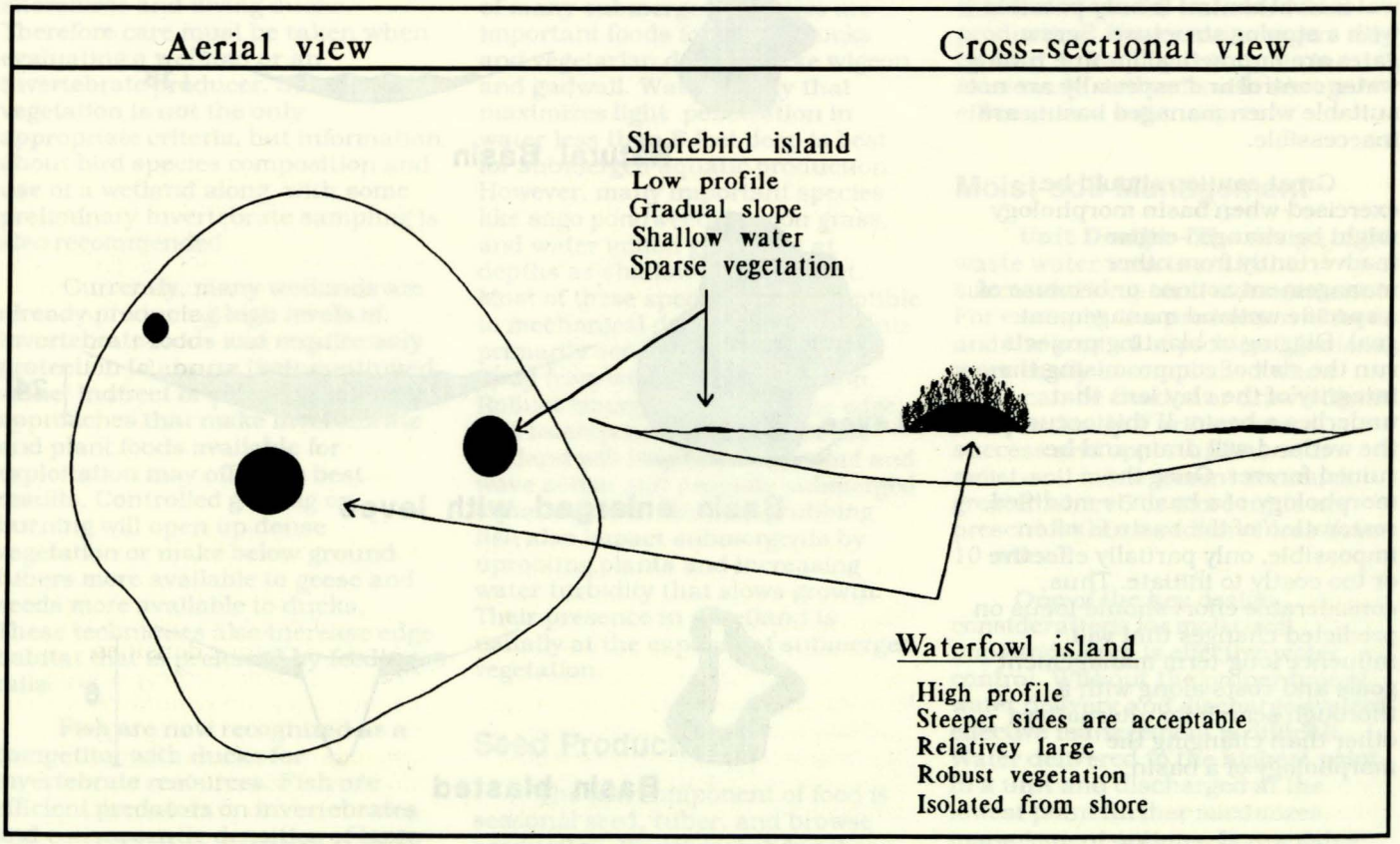



**Figure 24.** Characteristics of suitable nest islands for 2 groups of waterbirds.

elevational variation within a wetland. Because the highest seed densities are found in the top horizon of the soil, it is best to remove this layer prior to excavation activities and replace the material on the surface of the modified basin. This will assure seed bank retention and avoid the need for artificial seeding.

Water levels may be raised in some wetlands by constructing a levee at the lowest end of the basin that prevents runoff during high water. This allows water to raise along the natural basin contour, maximizing waterbird use. Of the three techniques, levees are the best choice because they cause the minimum impact to wetland function while achieving the maximum results. If levees are constructed, consideration should be given to including a water control structure. A structure is essential to maximize future management options and effective water level control is only possible with a stoplog structure. Screw gates are impractical for fine tuning water control and especially are not suitable when managed basins are inaccessible.

Great caution should be exercised when basin morphology might be changed either inadvertently from other management actions or because of a specific wetland management goal. Digging or blasting projects run the risk of compromising the integrity of the clay lens that underlies a basin. If this occurs, the wetland will drain and be ruined forever. Once the morphology of a basin is modified, restoration of the basin is often impossible, only partially effective or too costly to initiate. Thus, considerable effort should focus on predicted changes that will influence long-term management goals and costs along with a thorough search for alternatives other than changing the morphology of a basin.

## Food Production

### Invertebrates

One of the primary means of attracting larger numbers of wetland birds is through the production of greater invertebrate and plant food resources. Invertebrate foods are critical during the egg laying and brood raising period. Invertebrate biomass production is maximum in early successional wetlands with clear water. These wetlands may or may not have extensive amounts of vegetation present. The invertebrate community is characterized by low diversity but high abundance of drought resistant taxa like copepods, fairy shrimp, mayflies, mosquitoes, and daphnia. As the wetland slowly dries, invertebrate foods concentrate when water levels recede slowly and are made available for foraging birds.

Management strategies to maintain invertebrate populations in montane wetlands are mostly passive. Maintaining water quality and protecting the short flooding periods is the best way to maintain high production in ephemeral wetlands. Increasing the flooding duration with the goal of prolonging invertebrate availability may

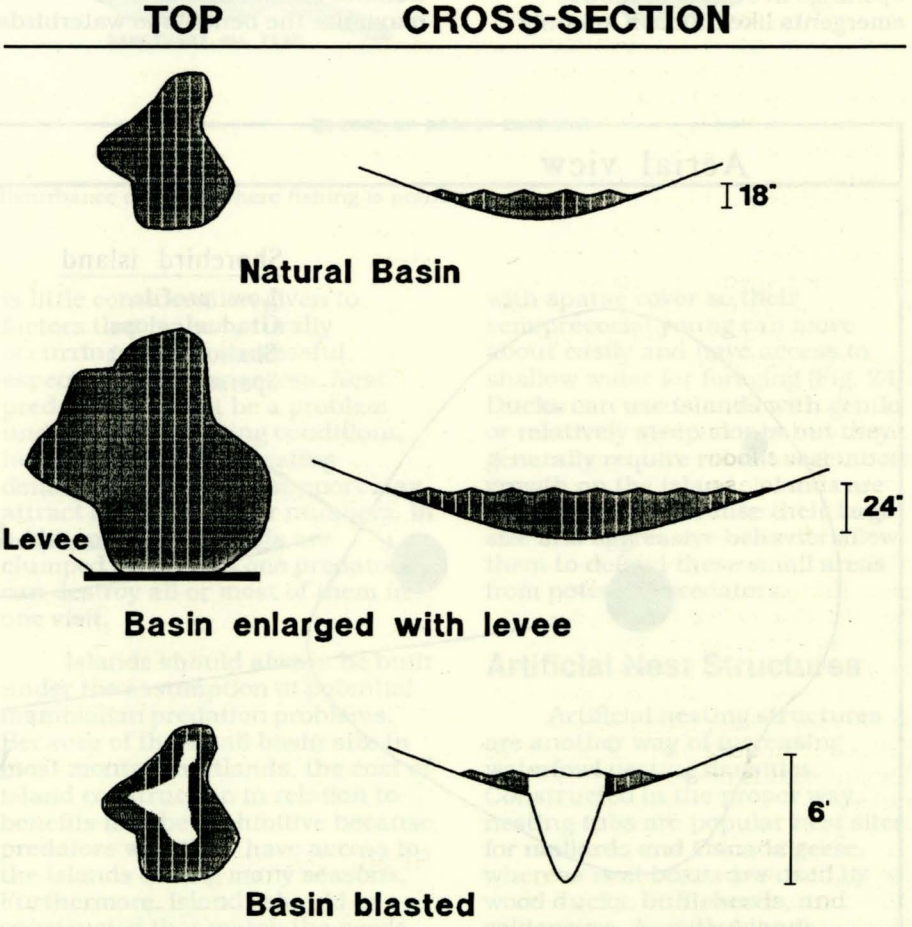



**Figure 25.** Effects of two management techniques to increase flooding depth and duration (shaded area represents functional waterfowl foraging area).

actually reduce the abundance or biomass of some invertebrates in these ephemeral sites. When the hydrology is changed by prolonged flooding, a shift in species composition and a decrease in productivity often results.

In semipermanent or permanent wetlands the invertebrate community is often more diverse and complex with larger numbers of predator species that may result in lower overall biomass of invertebrates/unit area. Detritivores and periphytic species like amphipods and snails dominant these systems. Production and diversity in these more permanent wetlands is best when extensive submerged aquatic vegetation like smartweed, water milfoil, and chara develop and are interspersed with mud substrates. Several invertebrate groups like midges and aquatic worms occupy benthic areas devoid of submergent vegetation. These groups are important food to shorebirds and diving ducks. Therefore care must be taken when evaluating a wetland or an invertebrate producer. Submerged vegetation is not the only appropriate criteria, but information about bird species composition and use of a wetland along with some preliminary invertebrate sampling is also recommended.

Currently, many wetlands are already producing high levels of invertebrate foods and require only protection to assure their continued value. Indirect or passive approaches that make invertebrate and plant foods available for exploitation may offer the best results. Controlled grazing or burning will open up dense vegetation or make below ground tubers more available to geese and seeds more available to ducks. These techniques also increase edge habitat that is preferred by feeding rails.

Fish are now recognized as a competitor with ducks for invertebrate resources. Fish are efficient predators on invertebrates and consequently densities of large macroinvertebrate species ideal for laying females and ducklings are often lower in wetlands with fish populations. As a result, waterfowl densities typically are lower on wetlands with fish. Unless fish eradication is a viable management option, increasing invertebrate densities for waterbirds in wetlands with fish is difficult. It is more feasible and important to limit the number of important waterbird wetlands that become important fish lakes in the future. However, fish serve as important foods for piscivorous bird species, thus the presence of fish in a few wetlands within a wetland complex provides a valuable food resource.

## Submergent Vegetation

Submergents are true aquatics and require longer periods of flooding than emergent species, thus avoiding frequent desiccation is a primary concern for successful management. The leaves and tubers of many submerged aquatics are important foods for diving ducks and vegetarian dabblers like wigeon and gadwall. Water clarity that maximizes light penetration in water less than 8 feet deep is best for submerged aquatic production. However, many important species like sago pondweed, wigeon grass, and water milfoil grow best at depths as shallow as 2 to 3 feet. Most of these species are susceptible to mechanical disturbance and thus primarily occur in sheltered areas away from wind and wave action. Robust emergents around the edge and interspersed throughout the wetland will help minimize wind and wave action and promote submerged aquatic growth. Bottom grubbing fish also impact submergents by uprooting plants and increasing water turbidity that slows growth. Their presence in a wetland is usually at the expense of submerged vegetation.

## Seed Production

The last component of food is seasonal seed, tuber, and browse production. Plants supplying these resources typically germinate along a continuum during natural water level drawdown. Of the many species adapted to these conditions, some are valuable seed and browse producers while many have little or no value to waterfowl. Under natural conditions both desirable and undesirable species are present, the exact composition depends on wetland depth, drying rate, and timing of draw down. The technique of moist-soil management involves manipulating the timing and rate of wetland draw downs to maximize the component of desirable plant species occurring in a wetland. Effective management requires the capability to draw down or flood wetlands when necessary and to control water levels within several inches. Food resources are made available to migrating waterbirds by flooding in fall.

The size and distribution of montane wetlands, the scarcity of water, and complex water rights laws precludes the extensive use of this technique for waterbird food production. However, managers may be able to employ this tactic in man-made wetlands with sewage effluent as a water source.

## Moist-soil Management

**Unit Design** - The design of the waste water area is critical to successful long-term management. For example, the production of foods and the control of problem plants is more easily accomplished when units can be flooded or drawn down independently. Furthermore, success and opportunities with moist-soil management are much greater when 6 or more units are present within a radius of less than 10 miles.

One of the key design considerations for moist-soil impoundments is effective water control. Without the proper type of water delivery and discharge system, effective management is difficult. Water delivered to the highest point in a unit and discharged at the lowest point further maximizes management options. Screw gates are suitable for inlet structures but

not as water level control structures. Stop-log structures are the best and cheapest approach to controlling water levels within a unit. Stop-log structures permit the subtle changes in water levels necessary to optimize vegetation responses in an impoundment.

**Management Strategies** - Because of the relatively short growing season at higher elevations, the draw down period to stimulate production of plant foods is relatively short. Draw downs later than July 1 are unlikely to produce foods. In addition, the draw downs should be slow in order to maintain the ideal conditions for food production. At these elevations in Arizona, a slow draw down should continue over a period of two weeks.

Food production and use will be best if flooding and draw down are varied among the units (Fig. 26). The best strategy is to vary the timing, duration, and depth of flooding and the timing of draw downs among the units both within and among years. By incorporating the semipermanent management regime within this scenario, a diversity of foods, foraging habitats, as well as breeding and brood cover would be made available for waterbirds from the time of their arrival in spring until their departure in fall. Rotating specific units from seasonal to semipermanent across years will help minimize problems associated with stable water regimes, while still providing all habitat types during every year. Those species with strong homing tendencies would likely find a continuing supply of needed habitats and foods within and among years. Thus, there is the opportunity to provide important life history requirements for a nucleus of waterbirds on these wastewater treatment sites.

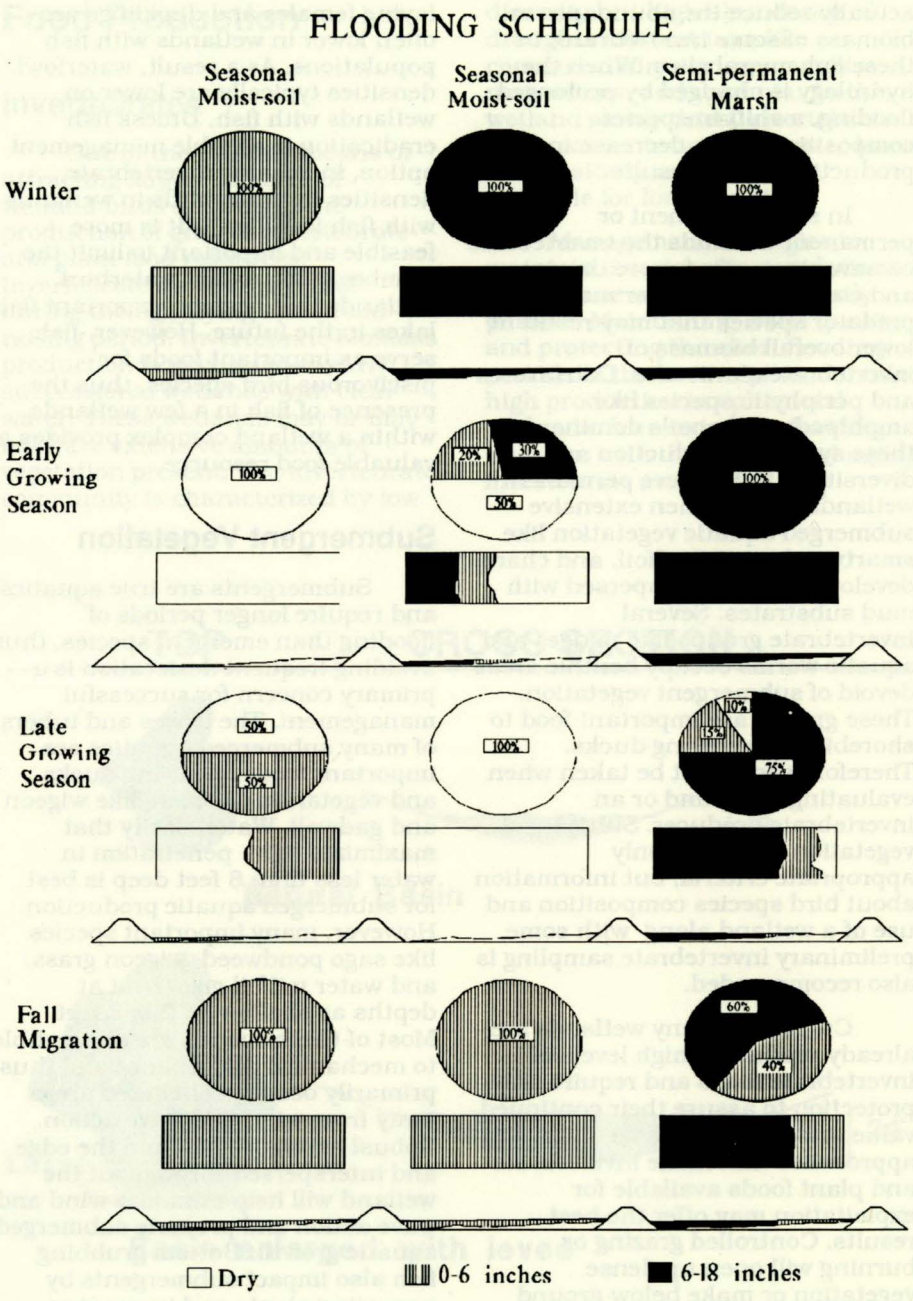



**Figure 26.** Strategies for water manipulations or wastewater wetland impoundments.

**Alternative Strategies** - As mentioned above, the opportunities for active management to produce food resources are limited. If active management is not possible, preventative management is the best option. Negative impacts on the wetlands basin can be minimized by protecting the surrounding watershed. Natural emergent plant food production can be safeguarded by maintaining gentle basin slopes and assuring that naturally occurring slow draw downs from evapotranspiration

continue. This protects the seed bank for the day when future management may be possible, allows natural plant responses, and provides a variety of habitats for waterbirds.

In certain situations some ephemeral wetlands might be converted to seasonal wetlands in an effort to supply different types of habitats or different foods in spring or fall. Large semipermanent or permanent reservoirs with water control structures may be managed to create good foraging conditions around their edges during fall by flooding natural vegetation or by lowering water levels to expose mud flats that can be used by shorebirds and green-winged teals. Although these strategies may seem insignificant because of the small area impacted, they may be the best given the current constraints to intensive management. Nevertheless such manipulations should provide the maximum potential for the future.

The dependable water supply from municipal discharge gives managers the flexibility needed to maximize food production and availability for waterbirds at all times of the year. In the mountains of Arizona the moist-soil or seasonally flooded sites can provide a good mix of foods for migrants as well as for some breeders.

# Suggested Reading


## Non-breeding Waterfowl Ecology

Bellrose, 1980
Brodsky and Weatherhead, 1985
Euliss and Harris, 1987
Haramis et al., 1986
Heitmeyer and Fredrickson, 1981
Heitmeyer and Vohs, 1984
Hepp, 1986
Hepp and Hair, 1984
Hepp et al., 1986
Kirby et al., 1988
Krapu, 1974
Sugden, 1973

## Non-breeding Waterfowl Management

Fleming, 1959
Fredrickson and Taylor, 1982
Hopper, 1973
Kadlec, 1962
Kadlec and Smith, 1989
Kirby et al., 1988
Meeks, 1969
Merendino et al., 1990
U.S. Fish and Wildlife Service, 1988 (13.4.4 and 13.4.9)

## Breeding Waterfowl Ecology

Bellrose, 1980
Burgess et al., 1965
Cowardin et al., 1985
Crabtree et al., 1989
Drewien and Fredrickson, 1970
Duebbert, 1966
Duncan, 1986
Heitmeyer and Fredrickson, 1981
Joyner, 1983
Kaminski, 1987
Kantrud and Stewart, 1977
Kirby et al., 1988
Krapu, 1981
Krapu et al., 1983
Lokemoen, 1966
Low, 1941
Low, 1945
Murkin and Kadlec, 1986
Myers, 1982
Owen and Reinecke, 1979
Spencer, 1953
Sugden, 1973

## Breeding Waterfowl Management

Burgess et al., 1965
Cowardin et al., 1985
Drewien and Fredrickson, 1970
Giroux, 1981
Higgins and Barker, 1982
Hoffman, 1970
Hopper, 1973
Kantrud, 1986
Kirby et al., 1988
Kirsch, 1969
Kirsch et al., 1979
Strohmeyer and Fredrickson, 1967
Szymczak, 1975
Willms and Crawford, 1989

## Wetland Wildlife

Anderson, 1950
Arner, 1963
Brown, 1985
Eddleman et al., 1988
Fredrickson and Reid, 1986
Kadlec, 1962
King and Hunt, 1967
Kirby et al., 1988
Lowe, 1964
Robel, 1961
Seastedt and Crossley, 1984
Weller and Spatcher, 1965

## Hydrology

Bouldin et al., 1972
Fredrickson and Reid, 1990
Fredrickson and Taylor, 1982
Gosselink and Turner, 1978
Kadlec, 1986a
Kadlec, 1986b
Kirby et al., 1988
Merendino et al., 1990
Mitsch and Gosselink, 1986
Weller and Spatcher, 1965

## Wetland Plants

Anderson, 1950
Armstrong, 1978
Danell and Sjoberg, 1982
Fredrickson and Taylor, 1982
Kadlec, 1962
Kantrud, 1986
Kearney and Peebles, 1960
Kirby et al., 1988
Krull, 1970
Leck, 1989
Nelson and Kadlec, 1984
Riemer, 1984
Scott and Wasser, 1980
Sculthorpe, 1967
Smith and Kadlec, 1983
Smith et al., 1984
Smith and Kadlec, 1985
Stewart and Kantrud, 1971
van der Valk, 1981
van der Valk, 1986
van der Valk and Davis, 1978
Weller and Spatcher, 1965
Wentz et al., 1974

## Wetland Invertebrates

Barber and Kevern, 1973
Danell and Sjoberg, 1982
Joyner, 1980
Kadlec, 1962
Kirby et al., 1988
Krull, 1970
Martin and Uhler, 1939
Murkin and Wrubleski, 1988
Nelson and Kadlec, 1984
Oberndorfer et al., 1984
Pennak, 1953
Resh and Rosenberg, 1984
Smock and Stoneburner, 1980
U.S. Fish and Wildlife Service, 1988 (13.3.1, 13.3.2, 13.3.3)
Voigts, 1976

## Nutrient Cycling

Cole and Fisher, 1979
Good et al., 1978
Kadlec, 1979
Kadlec, 1986a
Kadlec, 1986b
Kirby et al., 1988
Mitsch and Gosselink, 1986
Webster and Patten, 1979

## Decomposition

Davis and Turner, 1978
Good et al., 1978
Kirby et al., 1988
Mitsch and Gosselink, 1986
Smock and Stoneburner, 1980
van der Valk, 1986

## Wetland Complexes

Brown and Dinsmore, 1986
Diamond, 1975
Flake, 1978
Fredrickson and Reid, 1990
Fredrickson and Taylor, 1982
Heitmeyer and Fredrickson, 1981
Heitmeyer and Vohs, 1984
U.S. Fish and Wildlife Service, 1988 (13.2.1)
Weller, 1978

## Grazing

Kirsch, 1969
Kirsch et al., 1979
Mundinger, 1976
Ringelman, 1991
Smith and Kadlec, 1985

## Nesting Islands

Drewien and Fredrickson, 1970
Duebbert, 1966
Duncan, 1986
Giroux, 1981
Ringelman, 1991
Willms and Crawford, 1989

## Moist-soil Management

Fredrickson and Taylor, 1982
Kadlec, 1962
Kirby et al., 1988
Leck, 1989
Meeks, 1969
Merendino et al., 1990
Smith and Kadlec, 1983
U.S. Fish and Wildlife Service, 1988 (13.4.9)

## Food Production

Anderson, 1950
Arner, 1963
Barber and Kevern, 1973
Fredrickson and Reid, 1990
Fredrickson and Taylor, 1982
Kadlec, 1962
Kirby et al., 1988
Leck, 1989
Merendino et al., 1990
Ringelman, 1991
Smith and Kadlec, 1983
Smith et al., 1984
Smith and Kadlec, 1985
U.S. Fish and Wildlife Service, 1988 (13.1.1 and 13.4.9)

## Wetland Management

Anderson, 1950
Brown and Dinsmore, 1986
Danell and Sjoberg, 1982
Diamond 1975
Fredrickson and Taylor, 1982
Kirby et al., 1988
Linde, 1985
Meeks, 1969
Merendino et al., 1990
Nelson and Kadlec, 1984
Provost, 1948
Ringelman, 1991
Smith and Kadlec, 1983
Smith and Kadlec, 1985
Strohmeyer and Fredrickson, 1967
U.S. Fish and Wildlife Service, 1988 (13.1.2)
van der Valk and Davis, 1978
Weller, 1978
Wentz et al., 1974

# Selected Literature


Anderson, J. W. 1950. Some aquatic vegetation changes following fish removal. J. Wildl. Manage. 14:206-209.

Armstrong, W. 1978. Root aeration in the wetland condition. Pages 269- 298. in D. D. Hook and R. M. Crawford, eds. Plant life in anaerobic environments. Ann Arbor Science Pub. Ann Arbor.

Arner, D. H. 1963. Production of duck food in beaver ponds. J. Wildl. Manage. 27:76-81.

Barber, W. E. and N. R. Kevern. 1973. Ecological factors influencing macroinvertebrate standing crop distribution. Hydrobiologia 43:53- 75.

Bellrose, F. 1980. Ducks, geese, and swans of North America. Stackpole press, Harrisburg. 540 pp.

Bouldin, D. R., D. J. Lathwell, E. A. Goyette, and D. A. Laver. 1972. Changes in water chemistry in marshes over a 12-year period following establishment. New York Fish and Game J. 20:129-146.

Brodsky, L. H., and P. J. Weatherhead. 1985. Time and energy constraints on courtship in wintering American black ducks. Condor 87:33-36.

Brown, D. E. 1985. Arizona wetlands and waterfowl. Univ. of Arizona press, Tucson.

Brown, M. and J. J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. J. Wildl. Manage. 50:392- 397.

Burgess, H. H., H. H. Prince and D. L. Trauger. 1965. Blue-winged teal nesting success as related to land use. J. Wildl. Manage. 29:89- 95.

Cole, J. J. and S. G. Fisher. 1979. Nutrient budgets of a temporary pond. Hydrobiologia 63:213-222.

Cowardin, L. M., D. S. Gilmer and C. W. Shaiffer. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildl. Monogr. 92. 37 pp.

Crabtree, R. L, L. S. Broome and M. L. Wolfe. 1989. Effects of habitat characteristics on gadwall nest predation and nest-site selection. J. Wildl. Manage. 53:129-137.

Danell, K. and K. Sjoberg. 1982. Successional patterns of plants, invertebrates and ducks in a man-made lake. J. Appl. Ecol. 19:395- 409.

Davis, J. G. and R. E. Turner. 1978. Litter decomposition in Prairie glacial marshes. Pages 99-115 in R. Good, D. Whigham, R. Simpson and C. Jackson, eds. Freshwater Wetlands. Academic press, New York.

Diamond, J. M. 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. Biol. Conserv. 7:129- 146.

Drewien, R. C. and L. F. Fredrickson. 1970. High density of mallard nesting on a South Dakota island. Wilson Bull. 82:95-96.

Duebbert, H. F. 1966. Island nesting of the gadwall in North Dakota. Wilson Bull. 78:12-25.

Duncan, D. C. 1986. Influence of vegetation on composition and density of island-nesting ducks. Wildl. Soc. Bull. 14:158-160.

Eddleman, W. R., F. L. Knopf, B. Meanley, F. A. Reid, and R. Zembal. 1988. Conservation of North American Rallids. Wilson Bull. 100:458-475.

Euliss, N. H., Jr. and S. W. Harris. 1987. Feeding ecology of northern pintails and green-winged teal wintering in California. J. Wildl. Manage. 51:724-732.

Flake, L. D. 1978. Wetland diversity and waterfowl. Pages 312-319 in P. E. Greeson, J. R. Clark and J. E. Clark, eds. Wetland function and values: the state of our understanding. American Water Resources Association.

Fleming, W. B. 1959. Migratory waterfowl of Arizona. Arizona Game and Fish Wildlife Bull. No. 5. 74 pp.

Fredrickson, L. H. and F. A. Reid. 1986. Wetland and riparian habitats: a nongame management overview. Pages 59-96 in J. B. Hale, L. B. Best and R. L. Clawson, eds. Management of non-game wildlife in the midwest: a developing art. North Cent. Sect. Wildl. Soc., Chesea, Mich.

Fredrickson, L. H. and F. A. Reid. 1990. Impacts of hydrologic alteration on management of freshwater wetlands. Pages 71-90 in Static Wetland Management Symposium. 51st Midwest Fish and Wildlife Conference, Springfield, IL.

Fredrickson, L. H. and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. U. S. Fish and Wildl. Ser., Res. Publ. 148, 29 pp.

Giroux, J. 1981. Use of artificial islands by nesting waterfowl in southeastern Alberta. J. Wildl. Manage. 45:669-679.

Good, R. E., R. L. Simpson and D. F. Whigham. 1978. Freshwater wetlands: Ecological processes and management potential. Academic Press, New York 377 pp.

Gosling, J. G. and R. E. Turner. 1978. The role of hydrology in freshwater wetland ecosystems. Pages 63-78 in R. Good, D., R. Simpson and C. Jackson, eds. Freshwater Wetlands. Academic press, New York.

Haramis, G. M., J. D. Nichols, K. H. Pollock and J. E. Hines. 1986. The relationship between body mass and survival of wintering Canvasbacks. Auk 103:506-524.

Heitmeyer, M. E. and L. H. Fredrickson. 1981. Do wetland conditions in the Mississippi Delta hardwoods influence mallard recruitment? Trans. North Am. Wildl. and Nat. Resour. Conf. 46:44-57.

Heitmeyer, M. E. and P. A. Vohs. 1984. Characteristics of wetlands used by migrant dabbling ducks in Oklahoma. Wildfowl 35:61-70.

Hepp, G. R. 1986. Effects of body weight and age on the time of pairing of American black ducks. Auk 103:477-484.

Hepp, G. R. and J. D. Hair. 1984. Dominance in wintering waterfowl (Anatini): Effects on distribution of the sexes. Condor 86:251- 257.

Hepp, G. R., R. J. Blohm, R. E. Reynolds, J. E. Hines and J. D. Nichols, J. D. 1986. Physiological condition of autumn-banded mallards and its relationship to hunting vulnerability. J. Wildl. Manage. 50:177-183.

Higgins, K. F. and W. T. Barker. 1982. Changes in vegetation structure in seeded nesting cover in the prairie pothole region. U.S. Fish and Wildl. Service Spec. Sci. Rep. No. 242. 26 pp.

Hoffman, R. H. 1970. Waterfowl utilization of ponds blasted at Delta, Manitoba. J. Wildl. Manage. 34:568-593.

Hopper, R. M. 1973. Waterfowl use in relation to size and cost of potholes. J. Wildl. Manage. 36:459-468.

Joyner, D. E. 1980. Influence of invertebrates on pond selection. J. Wildl. Manage. 44:700-705.

Joyner, D. E. 1983. Parasitic egg laying in redheads and ruddy ducks in Utah: incidence and success. Auk:717-725.

Kadlec, J. A. 1962. The effect of a drawdown of a waterfowl impoundment. Ecology 43:267-281.

Kadlec, J. A. 1979. Nitrogen and phosphorus dynamics in inland freshwater wetlands. Pages 17-41 in T. A. Bookhout, ed. Waterfowl and wetlands: an integrated review, North Central Sect., The Wildlife Society, Madison, WI.

Kadlec, J. A. 1986a. Effects of flooding on dissolved and suspended nutrients in small diked marshes. Can. J. Fish. and Aqua. Sci. 43:1999-2008.

Kadlec, J. A. 1986b. Input-output nutrient budgets for small diked marshes. Can. J. Fish. and Aqua. Sci. 43:2009-2016.

Kadlec, J. A. and L. M. Smith. 1989. The Great Basin marshes. Pages 451- 474 in L. Smith, R. Pederson and R. Kaminski, eds. Habitat management for migrating and wintering waterfowl. Texas Tech. Press, Lubbock.

Kaiser, P. H., S. S. Berlinger and L. H. Fredrickson. 1979. Response of blue-winged teal to range management on waterfowl production areas in southeastern South Dakota. J. Range Manage. 32:295-298.

Kaminski, R. M., and E. A. Gluesing. 1987. Density- and habitat-related recruitment in mallards. J. Wildl. Manage. 51:141-148.

Kantrud, H. A. 1986. Effects of vegetation manipulation on breeding waterfowl in prairie wetlands-A literature review. U. S. Fish and Wildl. Ser. Tech. Rep. 3, 15 pp.

Kantrud, H. A. and R. E. Stewart. 1977. Use of natural basin wetlands by breeding waterfowl in North Dakota. J. Wildl. Manage. 41:243-253.

Kearney, T. H. and R. H. Peebles. 1960. Arizona flora. Univ. of California Press, Berkley. 1085 pp.

King, D. R. and G. S. Hunt. 1967. Effect of carp on vegetation in a Lake Erie marsh. J. Wildl. Manage. 50:212-217.

Kirby, R. E., S. J. Lewis and T. N. Sexson. 1988. Fire in North American wetland ecosystems and fire-wildlife relations: An annoted bibliography. U. S. Fish and Wildl. Ser. Bio. Rep. 88, 146 pp.

Kirsch, L. M. 1969. Waterfowl production in relation to grazing. J. Wildl. Manage. 33:821-828.

Kirsch, L. M., H. F. Duebbert and A. D. Kruse. 1979. Grazing and haying effects on habitats of upland nesting birds. Trans. N. Am. Wildl. and Nat. Res. Conf. 43:486-497.

Krapu, G. L. 1974. The feeding ecology of pintail hens during migration. Auk 91:278-290.

Krapu, G. L. 1981. The role of nutrient reserves in mallard reproduction. Auk 98:29-38.

Krapu, G. L., A. T. Klett and D. G. Jorde. 1983. The effect of variable spring water conditions on mallard reproduction. Auk 100:689-698.

Krull, J. N. 1970. Aquatic plant-macroinvertebrate associations and waterfowl. J. Wildl. Manage. 34:707-718.

Leck, M. A. 1989. Wetland seed banks. Pages 283-305 in M. A. Leck, V. T. Parker and R. L Simpson, eds. Ecology of Soil Seed Banks. Academic press, New York.

Linde, A. F. 1985. Vegetation management in water impoundments: alternatives and supplements to water-level control. Pages 51-60 in M. D. Knighton, ed. Water impoundments for wildlife: A habitat management workshop. U. S. Dep. Agric. For. Serv., St. Paul, Minn. 136 pp.

Lokemoen, J. T. 1966. Breeding ecology of the redhead duck in western Montana. J. Wildl. Manage. 30:668-681.

Low, J. B. 1941. Nesting of the ruddy duck in Iowa. Auk 58:506-517.

Low, J. B. 1945. Ecology and management of the redhead, Nyroca americana, in Iowa. Ecol. Monogr. 15:35-69.

Lowe, C. H. 1964. The vertebrates of Arizona.

Martin, A. C. and F. M. Uhler. 1939. Food of game ducks in the United States and Canada. U. S. Fish and Wildl. Ser. Res. Rep. 30, 308 pp.

Meeks, R. L. 1969. The effect of draw down date on wetland plant succession. J. Wildl. Manage. 33:817-821.

Merendino, M. T., L. M. Smith, G. R Murkin and R. L. Pederson. 1990. The response of prairie wetland vegetation to seasonality of draw down. Wildl. Soc. Bull 18:245-251.

Mitsch, W. F. and J. G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold Company Inc. New York 537 pp.

Mundinger, J. G. 1976. Waterfowl response to rest rotation grazing. J. Wildl. Manage. 40:60-68.

Murkin, H. R. and J. A. Kadlec. 1986. Relationships between waterfowl and macroinvertebrate densities in a northern prairie marsh. J. Wildl. Manage. 50:212-217.

Murkin, H. R. and D. A. Wrubleski. 1988. Aquatic invertebrates of freshwater wetlands: function and ecology. Pages 239-249 in D. D. Hook, ed. The ecology and management of wetlands. Croom Helm, London.

Myers, T. L. 1982. Ecology of nesting waterfowl on Anderson Mesa in north central Arizona. M.S. thesis, University of Arizona, Tucson. 78 pp.

Nelson, J. W. and J. A. Kadlec. 1984. A conceptual approach to relating habitat structure and macroinvertebrate production in freshwater wetlands. Trans. N. Am. Wildl. and Nat. Res. Conf. 49:262-270.

Oberndorfer, R. Y., J. Vaun McArthur, J. R. Barnes and J. Dixon. 1984. The effect of invertebrate predators on leaf litter processing in an alpine stream. Ecology 65:1325-1331.

Owen, R. B., Jr. and K. J. Reinecke. 1979. Bioenergetics of breeding dabbling ducks. Pages 71-99 in T. A. Bookhout, ed. Waterfowl and wetlands: an integrated review. Proc. 1977 Symp., North Centr. Sect., The Wildl. Soc., Madison, Wis. 147 pp.

Pennak, R. W. 1953. Fresh water invertebrates of the United States. Ronald Press Co., New York 769 pp.

Provost, M. M. 1948. Marsh blasting as a wildlife management technique. J. Wildl. Manage. 12:350-387.

Resh, V. H. and D. M. Rosenberg. 1984. The ecology of aquatic insects. Praeger, N.Y. 625 pp.

Riemer, 1984. Introduction to freshwater vegetation.

Ringelman, J. K. 1991. Evaluating and managing waterfowl habitat. Colorado Dept. of Nat. Res. Wildl. Div. Rep. 16, 46 pp.

Robel, R. J. 1961. The effects of carp populations on the production of waterfowl food plants. Trans. N. Am. Wildl. and Nat. Res. Conf. 26:147-159.

Scott, T. G. and C. H. Wasser. 1980. Checklist of North American plants for wildlife biologists. The Wildlife Society. 58 pp.

Sculthorpe, R. 1967. The biology of aquatic vascular plants. St. Martin's Press.

Seastedt, T. R. and D. A. Crossley Jr. 1984. The influence of Arthropods on ecosystems. BioScience 34:157-161.

Smith, L. M. and J. A. Kadlec. 1983. Seedbanks and their role during drawdown of a North American marsh. J. Appl. Ecol. 201:673-684.

Smith, L. M., J. A. Kadlec and P. V. Fonnesbeck. 1984. Effects of prescribed burning on nutritive quality of marsh plants in Utah. J. Wildl. Manage. 48:285-288.

Smith, L. M. and J. A. Kadlec. 1985. Fire and herbivory in a Great Salt Lake Marsh. Ecology 66:259-265.

Smock, E. A. and D. L. Stoneburner. 1980. The response of macroinvertebrates to aquatic macrophyte decomposition. Oikos 35:397-403.

Spencer, H. E. 1953. The cinnamon teal (Anas cyanoptera): its life history, ecology, and management. M.S. Thesis, Utah State Univ., Logan. 184 pp.

Stewart, R. E. and H. A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U. S. Fish and Wildl. Serv. Res. Pub. 92 pp.

Strohmeyer, D. L. and L. H. Fredrickson. 1967. An evaluation of dynamited potholes in northwest Iowa. J. Wildl. Mange. 31:525-532.

Sugden, L. G. 1973. Feeding ecology of pintail, gadwall, American wigeon, and lesser scaup ducklings in southern Alberta. Rep Ser. 24. Can. Wildl. Serv., Ottawa, Ontario. 45 pp.

Swanson, G. A. 1977. Diel food selection by Anatinae on a waste- stabilization system. J. Wildl. Manage. 41:226-231.

Szymczak, M. R. 1975. Canada goose restoration along the foothills of Colorado. Colorado Div. Wildl. Tech. Publ. 31. 63 pp.

U.S. Fish and Wildlife Service. 1988. Waterfowl management handbook. U. S. Fish and Wildl. Ser. Leafl. Series 13.

van der Valk, A. G. 1981. Succession in wetlands: a Gleasonian approach. Ecology 62:688-696.

van der Valk, A. G. 1986. The impact of litter and annual plants on recruitment from the seed bank of a lacustrine wetland. Aqua. Bot. 24:13-26.

van der Valk, A. G., and C. B. Davis. 1978. The role of seed banks in the vegetation dynamics of prairie glacial marshes. Ecology 59:322-335.

Voigts, D. K. 1976. Aquatic invertebrate abundance in relation to changing marsh vegetation. Am. Mid. Nat. 95:31-322.

Webster, J. R. and B. C. Patten. 1979. Effects of watershed perturbation on stream potassium and calcium dynamics. Ecol. Monogr. 49:51-72.

Weller, M. W. 1978. Wetland Habitats. Pages 210-234 in P. E. Greeson, J. R. Clark and J. E. Clark, eds. Wetland functions and values: the state or our understanding. American Water Resources Association, Minneapolis.

Weller, M. W. and C. E. Spatcher. 1965. Role of habitat in the distribution and abundance of marsh birds. Spec. Rep. Iowa Agri. Home Econ. Exp. Stn. 43:1-31.

Wentz, W. A., R. L. Smith and J. A. Kadlec. 1974. A selected annotated bibliography on aquatic and marsh plants and their management. Univ. Michigan School of Natural Resources. 190 pp.

Willms, M. A. and R. D. Crawford. 1989. Use of earthen islands by nesting ducks in North Dakota. J. Wildl. Manage. 53:411-417.

# Appendix 1

## List of Common and Scientific Names of Animals Appearing in the Text, Tables, and Figures

### Invertebrates

Copepods, *Copepods*
Waterfleas, *Cladocera*
Fairy shrimp, *Anostraca*
Seed shrimp, *Ostracoda*
Aquatic earthworms, *Oligochaeta*
Scuds, *Amphipods*
Horseflies, *Tabanidae*
Mosquitoes, *Culicidae*
Craneflies, *Tipulidae*
Backswimmers, *Notonectidae*
Water boatmen, *Corixidae*
Damselflies, *Zygoptera*
Dragonflies, *Anisoptera*
Midges, *Chironomid ae*
Predatory diving beetles, *Dytisidae*
Water scavenger beetles, *Hydrophilidae*
Snails, *Lymnidae, Physidae,* and *Planorbidae*

### Fish

Northern pike, *Esox lucius*
Minnows, *Cyprinidae* spp.
Golden shiner, *Notemigonus chrysoleucus*
Suckers, *Cutostomidae* spp.
Green sunfish, *Lepomis cyanellus*

### Amphibian/Reptiles

Tiger salamander, *Ambystoma tigrinum nebulosum*
Cricket frog, *Pseudacris triseriata*
Leopard frog, *Rana pipiens*
Western garter snake, *Thamnophis elegans*
Arizona treefrog, *Hyla wrightorum*

### Birds

Eared grebe, *Podiceps nigricollis*
Pied-billed grebe, *Podilymbus podiceps*
American bittern, *Botaurus lentiginosus*
Great-blue Heron, *Ardea herodias*
Black-crowned night-heron, *Nycticorax nycticorax*
White-faced ibis, *Plegadis falcinellus*
Canada goose, *Branta canadensis moffiti*
Mallard, *Anas platyrhynchos*
Pintail, *Anas acuta*
Green-winged teal, *Anas crecca*
Blue-winged teal, *Anas discors*
Cinnamon teal, *Anas cyanoptera*
Northern Shoveler, *Anas clypeata*
Gadwall, *Anas strepera*
American Widgeon, *Anas americana*
Canvasback, *Aythya valisineria*
Redhead, *Aythya americana*
Ring-necked duck, *Aythya collaris*
Bufflehead, *Bucephala albeola*
Ruddy duck, *Oxyura jamaicensis*
Osprey, *Pandion haliaetus*
Bald eagle, *Haliaetus leucocephalus*
Northern harrier, *Circus cyaneus*
Merlin, *Falco columbarius*
Peregrin falcon, *Falco peregrins*
Virginia rail, *Rallus limicola*
Sora, *Porzana carolina*
American coot, *Fulica americana*
Sandhill crane, *Grus canadensis*
Killdeer, *Charadrius vociferus*
Black-necked stilt, *Himantopus mexicanus*
American avocet, *Recurvirostra americana*
Wilson's phalarope, *Steganopus tricolor*
Spotted sandpiper, *Actitus macularia*
Western sandpiper, *Calidiris mauri*
Long-billed dowitcher, *Limnodromus scolopaceus*
Common snipe, *Gallinago gallinago*
Black tern, *Chlidonias niger*
Morning dove, *Zenaida macroura*
Common nighthawk, *Chordeiles minor*
Western kingbird, *Tyrannus verticalis*
Barn swallow, *Hirundo rustica*
American crow, *Corvus brachyrhynchos*
Northern raven, *Corvus corax*
Marsh wren, *Cistothonus palustris*
Common yellowthroat, *Geolypis trichas*
Savannah sparrow, *Passerculus sandwichensis*
Song sparrow, *Melospiza melodia*
Red-winged blackbird, *Agelaius phoeniceus*
Western meadowlark, *Sturnella magna*
Yellow-headed blackbird, *Xanthocephalus xanthocephalus*
Common grackle, *Quiscalus quiscula*

### Mammals

Muskrat, *Ondatra zibethica*
Raccoon, *Procyon lotor*
Mink, *Mustela vison*
Mule Deer, *Odocoileus hemionus*
Elk, *Cervus canadensis*
Pronghorn, *Antilocapra americana*
Beaver, *Castor canadensis*
Water shrew, *Sorex palustris*
Dwarf shrew, *Sorex manus*
Bobcat, *Lynx rufus*
Gray fox, *Urocyon cinereoargenteus*

# Appendix 2

## List of Common and Scientific Names of Plants Appearing in the Text

### Musk grass
*Chara* spp.

### Trees
Ponderosa pine, *Pinus ponderosa*
Pinyon pine, *P. edulis*
Utah juniper, *Juniperus osteosperma*
Willow, *Salix* spp.

### Cattail
Common cattail, *Typha latifolia*

### Burreed
*Sparaganium* spp.

### Pondweeds
Sago pondweed, *Potamogeton pectinatus*
Floatingleaf pondweed, *P. natans*
Grassleaf pondweed, *P. gramineus*
Northern pondweed, *P. alpinus*

### Wigeon grass
Common wigeon grass, *Ruppia maritima*

### Naiads
*Najas* spp.

### Plantains
American water plantain, *Alisma triviale*

### Waterweed
Canadian waterweed, *Eleodea canadensis*

### Wild celery
American wild celery, *Vallisneria americana*

### Grasses
Alpine timothy, *Phleum alpinum*
Arizona fescue, *Festuca arizonica*
Beardless pinegrass, *Blepharoneuron tricholepis*
Foxtail barley, *Hordeum jubatum*
Rice cutgrass, *Leersia oryzoides*
Millet, *Echinochloa crusgalli*
Mountain muhly, *Muhlenbergia montana*
Northern manna grass, *Glyceria borealis*
Panic grasses, *Panicum* spp.
Salt grass, *Distichlis stricta*
Sprangletop, *Leptochloa* spp.
Western wheatgrass, *Agropyron smithii*

### Bulrushes
Hardstem bulrush, *Scirpus acutus*

### Spike rushes
Longspike spike rush, *E. macrostachya*
Needle spike rush, *E. acicularis*

### Nutgrasses
*Cyperus* spp.

### Sedges
Beaked sedge, *Carex rostrata*
Water sedge, *C. aquatilis*

### Rushes
*Juncus* spp.

### Smartweeds
Water smartweed, *Polygonum coccineum*
Water Ladysthumb, *P. amphibium*
Big-seeded smartweed, *P. pensylvanicum*

### Coontail
*Ceratophyllum* spp.

### Buttercups
Water buttercup, *Ranunculus aquatilis*

### Sweet clover
Yellow sweet clover, *Melilotus efficinalis*

### Milfoil
Water milfoil, *Myriophyllum exalbescens*

### Bladderwort
Common bladderwort, *Utricularia vulgaris*

### Thistle
*Circium* spp.

# Appendix 3

## Common Plants of Montane Wetlands In Arizona

## Pondweeds

**Floatingleaf Pondweed** *(Potamogeton natans)*
(Broadleaved pondweed)
**Sago Pondweed**
*(P. pectinatus)* (Fennelleaf pondweed)

### General Description

Sago: wholly submersed aquatic, perennial from often large winter corms, stems growing from fleshy rhizomes, leaves linear 2-15 inches long. Floatingleaf: submersed leaves like sago, floating leaves oblong to elliptic, flowers on emersed spike. Leaves with membranous stipules, mostly alternate; both species produce nutlets 0.12-0.25 inches long. Other common species in montane Arizona include grassleaf pondweed *(P. gramineus)* and American pondweed *(P. nodusus)*.

### Ecology

Pondweeds float at or below the surface in quiet, fresh or brackish waters, often occurring in great masses in water from 1 to 6 feet deep. Pondweeds frequently grow in open areas among robust emergents like bulrush. In Arizona, sago is found primarily below 5,000 feet, the other three species occur to 9,000 feet. Maximum production for all species requires clear water, and sago requires soil salinities below 9 ppt TDS for young plants and 12 ppt TDS for mature plants.

### Wildlife Use

Pondweeds are desirable waterfowl foods, all parts of many species (including sago) are eaten. Rootstocks bear tubers about the size of a pea which are fed upon by divers and even dabblers in shallow water. Seeds are used by mallard, green-winged teal, pintail, and shoveler to name a few. Pondweed leaves make up a significant portion of wigeon and gadwall diets. Pondweeds use can be so heavy in the fall that dense aquatic beds may be undetectable after heavy bird use.

## HARDSTEM BULRUSH *(Scirpus acutus)* (Bull tule)

### Description

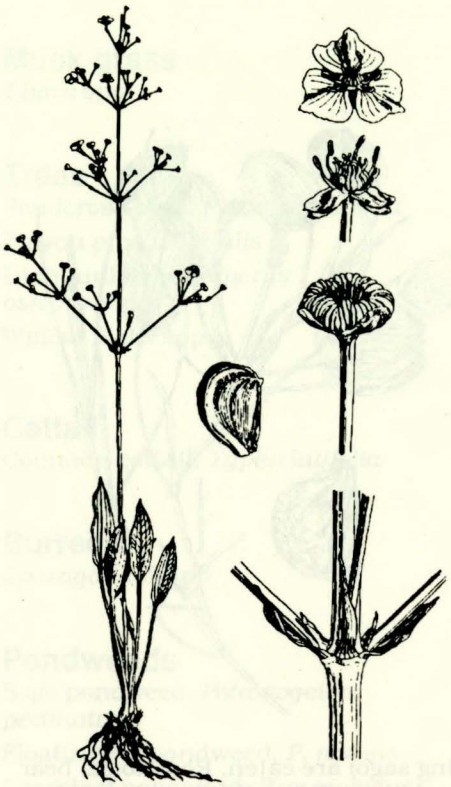
Perennial, culms up to 0.7 inches wide arising from thick brown rhizomes to 15 feet, leaves reduced to basal sheaths. Involucral leaf solitary, appears to be an extension of culm; spikelets numerous and in umbels. Very similar to *S. validus* which is found in Arizona up to 5,000 feet.

### Ecology

Hardstem bulrush is a common, often dominant emergent plant throughout semipermanent and around the edges of permanent wetlands and lakes with salinities <10 ppt. Found throughout the eastern two-thirds of Arizona between 2,500 and 9,000 feet. Spring drawdown to mudflats stimulates new growth from seeds, but mudflats are not necessary for growth to occur from rhizomes. Seed heads emerge in early summer and seeds mature by late summer or fall prior to plant senescence and root dormancy. Opening up over-grown stands can be achieved by a wetland drawdown that desiccates the plant followed by mowing or burning. Grazing may also be a temporary solution. Repeated drawdowns followed by flooding will promote maximum growth and expansion.

### Wildlife Use

The seeds of hardstem are taken by many species including teal, mallards, pintail and rails. The robust cover provides nesting habitat for a wide range of species including grebes, redheads, ruddy ducks, coots, rails, and blackbirds. Marshes with good interspersion of bulrush provide good brood and summer molting habitat.



**WATER PLANTAIN** (*Alisma* spp.)

### Description

Their seems to be some confusion about which species inhabits Arizona wetlands, both American water plantain *(A. triviale)* and *A. subcordatum* are mentioned. In general, plantains are aquatic or semi-aquatic perennial herbs with long petioled basal leaves oblong or lanceolate in shape, flowers on long stalk. The many white flowers 3 petaled. Fruit an achene, achenes situated in a whorl on the receptacle.

### Ecology

Found in Arizona from 4,000 to 8,000 feet. A perennial herb with thickened roots, water plantain commonly is found in areas that retain shallow water early in the growing season. Therefore, germination tends to be best following early spring drawdowns. In moist-soil impoundments, typically found in ditches, borrow areas, or units managed as semipermanent wetlands. Commonly found in association with spike rush, smartweeds, and sedges.

An early germinator, seeds ripen early in the season and the plants senesce allowing later germinating plants to grow.

### Wildlife Use

The achenes are eaten by waterfowl.

**ALPINE TIMOTHY** *(Phleum alpinus)*
(Mountain timothy, Wild timothy)

### Description

Culms 7.5-20 inches tall from a dense somewhat creeping base. Blades typically less than 4 inches long and 0.12-0.3 mm wide. Flowers on cylindric panicle, usually purplish, spikelets 1 flowered, laterally compressed with long stout awns giving the plant a bristly appearance. At a glance, alpine timothy differs from common cultivated timothy *(P. pratense)* in being shorter with a more egg shaped inflorescence.

### Ecology

Alpine timothy is the only native timothy species in North America. As the name implies, in Arizona alpine timothy is found predominantly in alpine and subalpine habitats in Apache and Coconino counties up to 12,000 feet. It also occurs at northern latitudes along the west coast and in Alaska where cool temperatures and moist conditions are conducive for growth. A cool season grass adapted to wet soil conditions, timothy is usually found in wet mountain meadows, around marshes and bogs, and along streams. Common plant species found in association with timothy include rushes, sedges, and willows. Reproduction is by means of shoots growing from the decumbent base and by seeds. One study found that 70% of the seeds, which ripen in August and September, were viable. This is considerably higher than many similar plants at those altitudes.

### Wildlife Use

Alpine timothy is highly desired for grazing by cattle, elk and deer. The plants remain good forage throughout the summer into fall. The species can withstand heavy trampling. Its growth habit may make it good nesting cover for cinnamon teal.

**FOXTAIL BARLEY** *(Hordeum jubatum)* (Squirrel tail)

### Description

Perennial, tufted culms 12-24 inches tall 0.1-0.25 inches wide, awns 0.75-0.25 inches long; nodding spikes 2-4 inches tall.

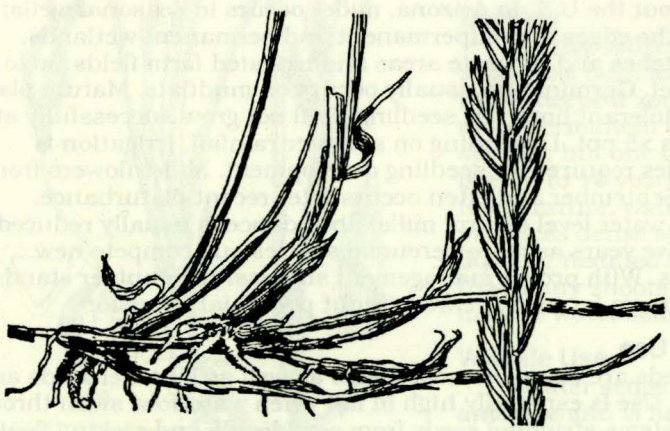
### Ecology

This perennial occurs in grass communities growing on moist saline and dry soils. In Arizona, foxtail occurs in Apache, Navajo, Coconino, and Maricopa counties up to 7,500 feet. Foxtail produces large amounts of wind and animal dispersed seed. Because of this excellent dispersal mechanism and because it is primarily avoided by grazers (see below), foxtail can become dominant in heavily grazed areas. Improving the forage quality of a grass community dominated by foxtail requires either a reduction in the grazing pressure, which will encourage the growth and spread of more desirable species or reseeding of desirable species following extensive cultivation. The first method is slow but often the only option open to managers of large dispersed areas.

### Wildlife Use

Young plants are eaten by cattle and native ungulates. However the mature plants with well developed seed heads are avoided and considered harmful to cattle, elk, deer and antelope. The long awns stick into the soft tissue of the mouth causing sores. Infection from these injuries can lead to death. Evidence of this disease was found in 70 of 193 elk carcasses examined in Wyoming in one winter. Waterfowl will nest in foxtail and regularly use shallowly flooded squirrel tail habitats in spring.

**WESTERN WHEATGRASS** *(Agropyron smithii)*
(Bluestem, Smith bluejoint)



### Description

Culms erect, usually glacous, from 12-24 inches high. Stems from creeping rhizomes; lemmas with short, straight awns; glumes rigid; erect spike 2.7-6.0 inches long, flowers overlapping.

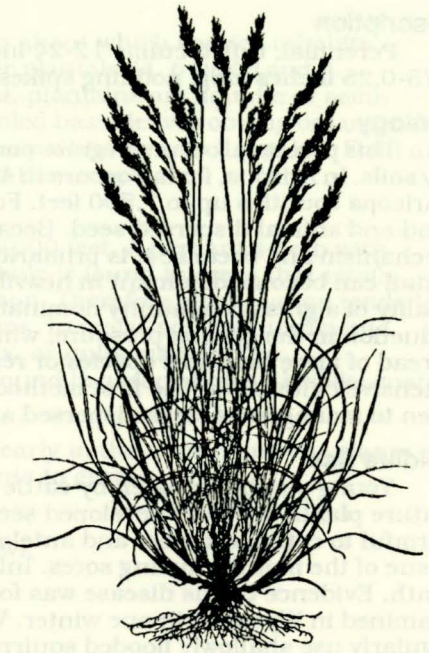
### Ecology

A native cool season grass growing between 3,500 and 7,500 feet in Arizona. Wheatgrass grows in a variety of soils and withstands dry conditions well. In areas with high alkalinities, other poor soil conditions or little rainfall, it is often the dominant or only plant. Most reproduction occurs from long underground rhizomes and the few seeds produced, mature late. Seed germination is early in this species. Not directly associated with wetlands, wheatgrass occupies higher sites around montane wetland basins.

### Wildlife Use

Wheatgrass is heavily utilized by elk and deer. Because of the habit of reproducing from rhizomes, wheatgrass can withstand moderate grazing pressure. When not overgrazed, its perennial nature may make it an excellent source of residual vegetation for nesting waterfowl in spring.

**ARIZONA FESCUE** *(Festuca arizonica)*
(Pine grass, mountain bunch grass)



### Description

Perennial, densely tufted culms 1-3 feet tall; blades numerous, elongate and glaucous; ligule short, narrow panicle 4-8 inches long, 5-7 flowers per spike; lemmas awnless or nearly awnless.

### Ecology

Mountain bunch grass is the most common fescue in Arizona. This densely tufted perennial occurs mostly between 2,500 and 10,000 feet. The species is abundant in open ponderosa pine areas and sloping mesas. It is usually associated with blue gramma, mountain muhly, pine dropseed and cinquefoil. It grows in a range of conditions from dry, shallow clay loams to sandy, gravely or rocky soils and moist shady areas. A slow grower, most growth occurs during the period of midsummer rains. Plants produce an abundance of viable seed.

### Wildlife Use

Because of its abundance, Arizona fescue is an important forage plant. The extensive root system allows Arizona fescue to withstand drought and trampling better than many species. However it does not withstand grazing pressure well and moderate pressure will significantly reduce cover. Seeding experiments have been largely ineffective. Damage can be greatly reduced with proper stocking levels and limiting grazing during late spring and early summer prior to the onset of summer rains. When near wetlands, this perennial may provide important residual cover for nesting waterfowl.

**WILD MILLET** *(Echinochloa crusgalli)*
(barnyard grass or water grass)

### Description

Annual, culms mostly erect, stout and flattened at base rising to 4 feet; wide panicle erect or nodding 4-8 inches long; leaves narrow, 2-6 inches long; inflorescence racemes along a common axis, spikelets crowded, awchess mostly 2-4 inches long.

### Ecology

Native to Europe, millet is now widespread on wet places throughout the U.S. In Arizona, millet occurs in seasonal wetlands, around the edges of semipermanent and permanent wetlands, along ditches and in waste areas and irrigated farm fields up to 7,000 feet. Germination usually occurs on mudflats. Mature plants are salt tolerant however, seedlings will not grow successfully at salinities >5 ppt. Depending on summer rainfall, irrigation is sometimes required for seedling development. Millet flowers from July to September and often occurs after recent disturbance. Without water level control millet abundance is usually reduced in successive years as more perennial species out-compete new seedlings. With proper management successful volunteer stands can be grown for many years without perennial intrusion.

### Wildlife Use

Seeds are eaten by most ducks as well as by other birds and rodents. Use is especially high in fall when waterfowl swim through flooded stems stripping seeds from seed heads and picking floating seeds from the water surface. Millet is most valuable when associated with other plant species that provide a variety of resource and habitat types.

## NORTHERN MANNA GRASS *(Glyceria borealis)*

### Description

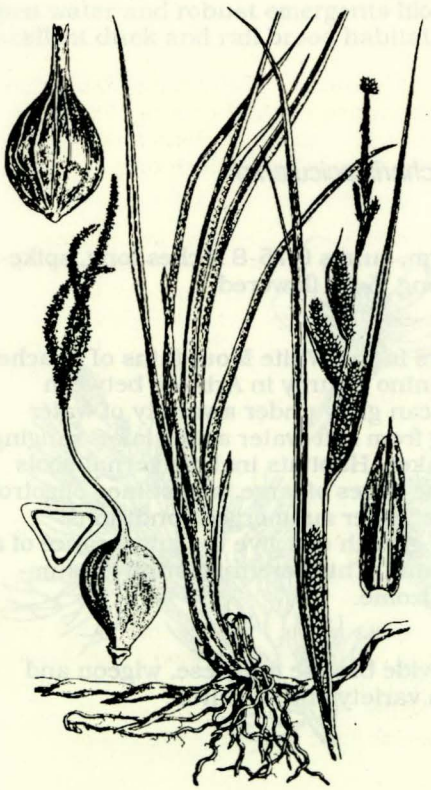
Culms erect or decumbent and rooted at base or with creeping rhizomes, 1-3 feet tall. Fibrous roots, round hollow stems, closed sheaths. Panicle mostly 0.7-1.5 inches long and bearing spikelets with from 6-12 flowers each.

### Ecology

Northern manna grass is one of 4 perennial mannas (Tall manna grass *(G. elata)*, American manna grass *(G. grandis)*, and Fowl manna grass *(G. striata)* are the others occurring in Arizona mostly between 7,000 and 9,000 feet. All species occur in wet meadows and along stream banks, however northern manna grass also grows readily in shallow standing water. This habit makes it a common plant in temporary and seasonal wetland basins. All species occur around the edges of more permanent wetlands. Some species are very shade tolerant. Northern manna grass grows in association with plants like sedges, millet, and rushes.

### Wildlife Use

Most manna grasses are good forage for ungulates, although the wet places they frequent can prevent extensive use until late summer. The seeds of manna grasses are used by waterfowl and rails.



## SEDGES

BEAKED SEDGE *(Carex rostrata)*
WATER SEDGE *(Carex aquatilis)*

### Description

Perennials, monoecious, culms 12-35 inches tall, leaves triangled, lower ones with well developed blades; rhizomes produce long horizontal stolons, achenes triangular, stigmas mostly 3, lower pistillate spikes erect; for water sedge achenes lenticular, stigmas mostly 2.

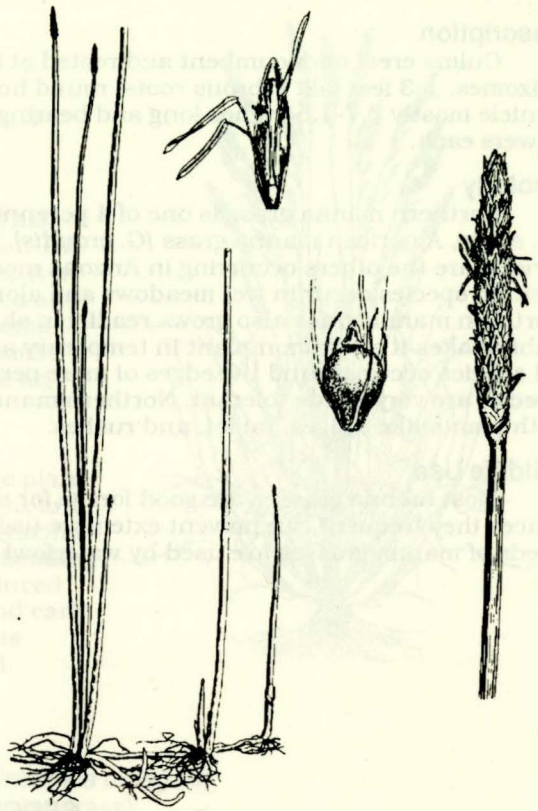
### Ecology

Water sedge is restricted primarily to the White Mountains. Beaked sedge has been found in Coconino, Apache and Pima counties. They occur in the deepest zones of temporary wetland basins and around the edges of more permanent basins. Shoot lifespan is predominantly 2 years for both species, but one study found water sedge shoots 6 years old. Root balls may live up to 10 years. Shoot density and height are influenced by temperature, water depth and permanence. Prolonged shallow flooding produces dense stands of shorter culmed individuals, whereas deep flooding resulted in less dense but taller individuals. Conditions dictate that many shoots do not reach maturity. Unlike some perennial sedges, all mature water sedge plants produce flowers.

### Wildlife Use

Water sedge provides good forage for grazers like elk, deer and antelope and is harvested for hay in many northern latitude countries. The seeds of sedge species are often used by waterfowl and rails. Many waterfowl nest in sedge meadows in Arizona.

## LONGSPIKE SPIKE RUSH *(Eleocharis macrostachya)*



### Description

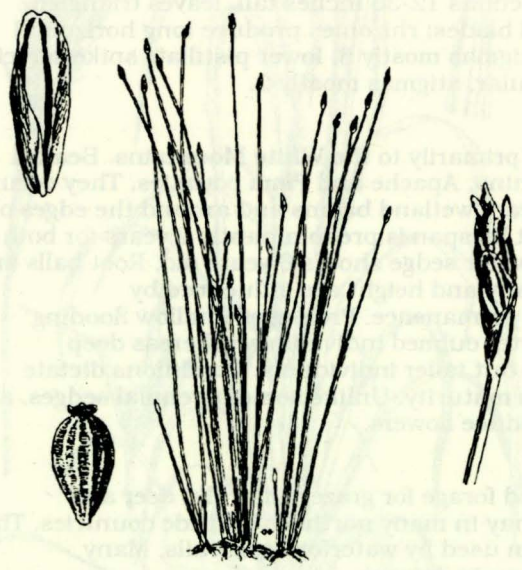
Perennial with long, creeping rhizomes; stout or slender erect culms, 6-12 inches tall and pale to dark green in color; leaves, without blades, reduced to basal sheaths; simple, tufted stems terminating in a solitary spikelet 0.5-2.0 inches long, not subtended by an involucre.

### Ecology

Common and widespread in fresh and alkali marshes, ponds, vernal pools, and ditches. Prevalent in seasonal and semipermanent wetlands. The most common spike rush in northern and central Arizona, it occurs up to 6,500 feet. Plants germinate in several inches of water which should be maintained without overtopping growing seedlings until plants are 8 inches tall then be allowed to dry as plant matures. Seed production can be increased by summer irrigation.

### Wildlife Use

New growing shoots provide browse for geese, wigeon and gadwall. Seeds are eaten by a variety of waterbirds. In wetlands with dense stands of spike rush, creating openings in late summer will create better conditions for waterfowl and rail use in fall and brood use in spring.



## NEEDLE SPIKE RUSH *(Eleocharis acicularis)*

### Description

Perennial, stolons filiform, culms 0.75-8 inches long, spikelets terminal, 0.1-.3 inches long, 5-10 flowered.

### Ecologches

Needle spike rush occurs in the White Mountains of Apache County and throughout Coconino County in Arizona between 7,000 and 9,000 feet. Plants can grow under a variety of water chemistry conditions ranging from soft-water acidic lakes ranging from pH 3.9-6.9 to alkaline lakes. Habitats include vernal pools as well as small ponds and the edges of large, sometimes oligotrophic lakes. Growth is possible under submerged conditions. During dry conditions, dense growth can give the appearance of a green carpet covering the ground. This perennial survives summer drought as a dormant rhizome.

### Wildlife Use

New growing shoots provide browse for geese, wigeon and gadwall. Seeds are eaten by a variety of waterbirds.

**SMARTWEEDS:** *(knotweeds)*
**WATER LADYSTHUMB** *(Polygonum amphibium)*
**WATER SMARTWEED** *(Polygonum coccineum)* (marsh knotweed)

### General Description

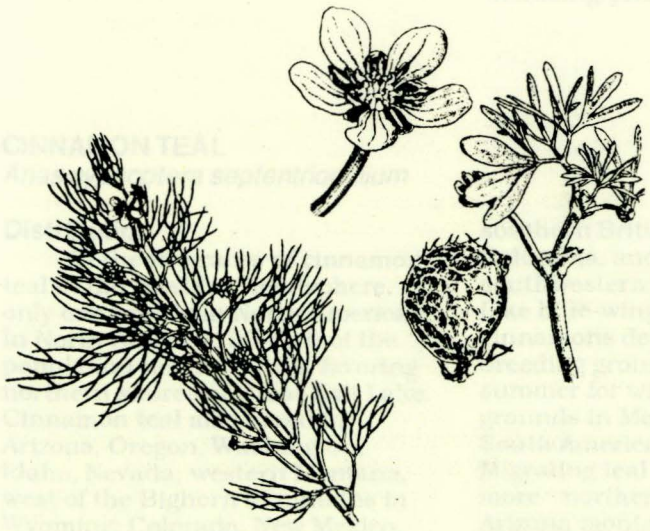
Amphibious, aquatic, or terrestrial perennial. Stem jointed, often swollen at nodes. Stems submersed, floating and rooting at the nodes, or erect and aerial, arising from creeping rhizomes in Ladysthumb. Leaves entire, simple and alternate. The leaves of ladysthumb oblong to elliptic, 2-4 inches long. Leaves of water smartweed floating or aerial, lanceolate to oblong, 3-6 inches long. Bright pink flowers of Ladysthumb in dense spikes 4-14 inches long. Similar colored flowers of water smartweed on elongated spikes of 0.7-3.2 inches, flowering in succession.

### Ecology

A wide range of smartweed species have evolved to inhabitat different wetland niches. In Arizona, water smartweed is found between 2,500-7,000 feet in seasonal, semipermanent, and permanent wetlands and seem to be able to tolerate both brackish and acidic water conditions. Water ladysthumb occurs from 5,000-9,000 feet in semipermanent and permanent wetlands. Ladysthumb is slightly more aquatic than smartweed. Both species establish on mudflats or in shallow water.

### Wildlife Use

Smartweeds are one of the me most heavily used plants by waterfowl and rails. Seed size and production varies among species but wherever smartweeds are found they are consumed by waterbirds. Because they grow in more aquatic habitats, water smartweed and water ladysthumb also provide good substrate for invertebrate populations. Where these species are mixed with open water and robust emergents like bulrush they provide excellent duck and rail brood habitat.



**WATER BUTTERCUP** *(Ranunculus aquatilis)*

### General Description

Herbaceous, floating, perennial aquatic. Submersed leaves filiform-dissected. Occasional floating leaves lobed. White flowers 6-10 inches in diameter, 5 deciduous petals sometimes greenish-yellow at base. Flowers produce many achenes.

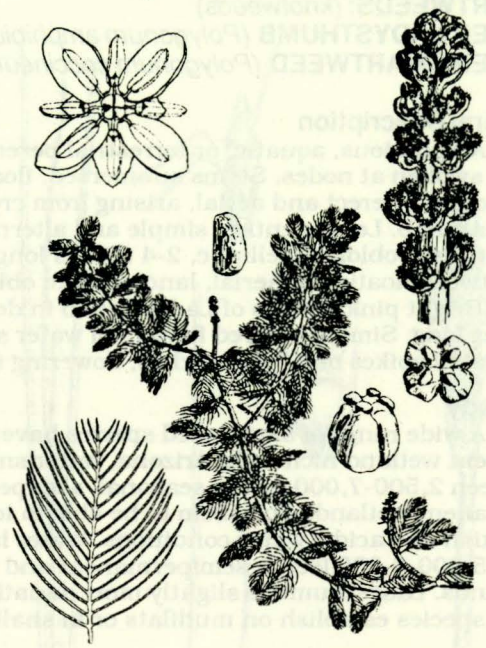
### Ecology

Water buttercup commonly grows in ponds, shallow lakes and slow moving rivers or creeks. Where common, the many emersed white flowers are quite attractive. Water buttercup is found in Arizona between 4,500 and 9,000 feet. Reproduction and dispersion is accomplished primarily by seeds, but fragmented pieces frequently drift to new places where they root and grow.

### Wildlife Use

Water buttercup is little used by waterfowl, although the seeds and vegetation are consumed occasionally, but the finely dissected leaves provide good invertebrate substrate.

## WATER MILFOIL *(Myriophyllum exalbescens)*



### General Description

Herbaceous, perennial, submersed aquatic, 0.5-1.5 inches long submersed leaves pinnately dissected in whorls of 3-4 around stem, emersed leaves linnear. Stems flexible and rooted. Small, dioecious, flowers on emersed spike, red or pink staminate flowers located on upper end of spike. Flowers summer to early fall.

### Ecology

Common plant in lakes and ponds or slow moving rivers or creeks. Occurs in semipermanent and permanent wetlands between 5,000 and 9,000 feet in Arizona. Grows in association with pondweeds, water ladysthumb, and bulrush. Although viable seeds are formed each year, the most effective means of reproduction and dispersion is via fragmentation. Terminal segments split off the main plant and float some distance eventually sinking, growing roots and resuming growth.

### Wildlife Use

Milfoil has value as a food for gadwall and wigeon and the seeds are occasionally consumed by divers. It may be used by coots and its leaf structure provides good invertebrate habitat.

# Appendix 4

## Common Birds of Montane Wetlands In Arizona

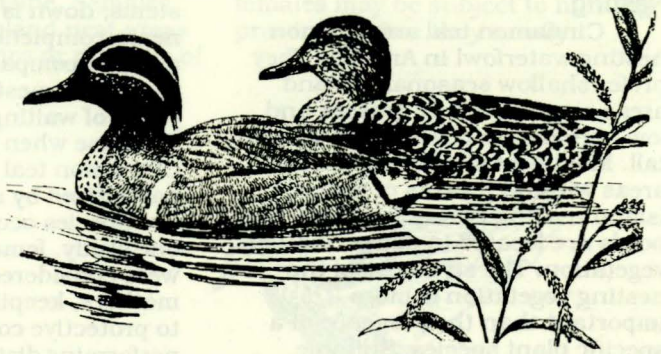
### American Green-Winged Teal
*Anas creeca carolinensis*

#### Distribution

There are three races of green-winged teal worldwide. The American green-winged teal (3 million) occurs across North America. Their vast breeding range extends from the Aleutians islands and northern Alaska, Saskatchewan, Manitoba, Ontario, Quebec, and Labrador, south to central California and northern New Mexico, eastward to Kansas and northeastward to Minnesota, Wisconsin, the Maritime Provinces and Newfoundland. Although, not as common as cinnamon teal, greenwings are regular nesters on semipermanent wetlands in Arizona. Fall migrant populations peak in Arizona from early to mid October as birds stop on route to wintering grounds in Mexico. Greenwings have an extensive winter range from coastal Alaska through southern United States and Mexico to Central America and northern South America. The largest concentration occurs in the playa lakes region of Texas and the coastal marshes of Texas and Louisiana. The second largest wintering population occurs in the Pacific Flyway.

#### Nesting

American green-winged teal are largely upland nesters with nest sites located 2-300 feet from water. In Arizona, nests are initiated from mid May to late June depending on altitude. Breeding birds use well hidden sites that are mainly dense shrubby or herbaceous vegetation distributed along marsh edges and on small ponds. They require less open water than do larger ducks. Greenwings build a nest of grass with feather lining amid dense stands of grass, weeds, willows and brush.



#### Food Habits

Greenwings prefer smaller seeds to large crop grains. They forage by tipping up in very shallow water along the edges of marshes and ponds or by walking on exposed mudflats where they sift seeds and invertebrates from the substrate. Favorite foods include seeds of bulrushes, pondweeds, smartweeds, millets, nutgrasses, sprangletop, panic grasses and spike rushes. When small seeds are lacking, teal use larger seeds including corn, wheat, and barley.

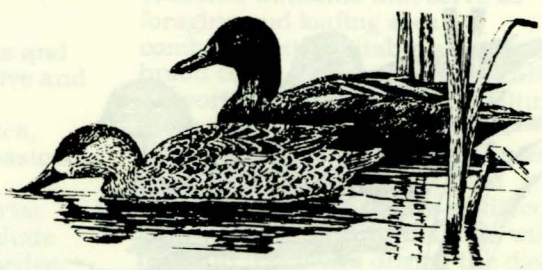
#### Habitat Use

Greenwings use many habitats. More than any other duck, they prefer small, shallow ponds with dense herbaceous cover near open-water. Greenwings breed primarily in semipermanent and permanent boreal forest wetlands, north of the prairie nesting grounds of many species. Thus, continental populations are less vulnerable to fluctuating wetlands conditions related to drought cycles and habitat loss from agriculture that have created problems for more southerly nesters like blue-winged teal, pintail and mallard. They winter most anywhere in the United States where open water remains. In Arizona this primarily includes wetlands along southern river drainages.

### CINNAMON TEAL
*Anas cyanoptera septentrionalium*

#### Distribution

Of the five races of cinnamon teal in the Western Hemisphere, only one breeds in North America. In North America, 50-58% of the population nests in Utah, favoring northern shores of Great Salt Lake. Cinnamon teal also breed in Arizona, Oregon, Washington, Idaho, Nevada, western Montana, west of the Bighorn Mountains in Wyoming, Colorado, New Mexico, southern British Columbia, and southwestern Alberta. Like blue-winged teal, cinnamons depart their breeding grounds in late summer for wintering grounds in Mexico and South America. Migrating teal from more northern breeding areas use Arizona montane wetlands in fall



and spring. Small numbers (100-200) may be found in Arizona lowland wetlands during winter.

### Nesting

Cinnamon teal are common nesting waterfowl in Arizona. They prefer shallow seasonal wetland areas surrounded by grasses and low herbaceous cover about 2 feet tall. Most nest sites are in marsh areas within 75 yards of water. Island nesting is very frequent. Nest bowls are located in dense, matted vegetation. The structure of the nesting vegetation is more important than the presence of a specific plant species. Suitable species in Arizona include salt grass, western wheatgrass, hardstem bulrush, sedges, and spike rush. Females will often build their nests under layed over residual vegetation, entering via an entrance tunnel. Nests are lined with dense grasses and other plant stems; down is added as the clutch nears completion. Home range core areas encompass about 30 square yards with nest sites within 100 yards of waiting sites. Home ranges decrease when nest density is high. Cinnamon teal are frequently parasitized by redheads when the two species occur sympatrically. In one study, female cinnamon teal were considered to be the best mothers, keeping their brood close to protective cover and vigirously performing distraction displays.

### Food Habits

Bulrush seeds, pondweed seeds and leaves, and salt grass seeds are consumed in greatest quantity by cinnamon teal, supplemented with small amounts of animal life, mostly insects and mollusks.

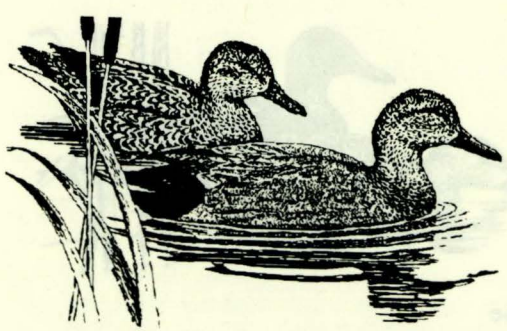
### Habitat Use

Cinnamon teals inhabit small, shallow water areas in marshes, parklands, and mountain valleys rich in submerged aquatics and surrounded by marsh plants. Preferred loafing include old muskrat houses, logs, or small points of land. Females keep broods near escape cover favoring small ditches, canals, and ponds where submerged aquatics and adjacent vegetation are plentiful. Favored feeding habitat is along the edge of tall marsh growth bordering the open water of a pond or slow flowing creek.

## GADWALL
*Anas strepera*

### Distribution

Unlike circumpolar nesting green-winged teal, gadwalls occur as one race throughout their extensive breeding range in the Northern Hemisphere. In North America, they breed primarily in mixed grasslands of the Dakotas and the prairie provinces of Canada, and secondarily in the parklands of the prairie provinces. A significant number nest in the intermountain marshes of the West. Other breeding areas occur in California, Colorado, Nebraska, and Wisconsin, with limited breeding in eastern Canada and on the Atlantic coast. Gadwall nest commonly in Arizona montane wetlands, in some locales they are second only to the mallard in abundance. Anywhere from 25,000 to 50,000 gadwall pass through Arizona during fall migration. The primary wintering area for gadwall is coastal Louisiana. Other important wintering areas include coastal Texas, California's central valley, and the west coast of Mexico.



### Nesting

Gadwall are one of the latest nesting dabbler species. In Arizona, nest initiation occurs from late May to early July; peak nest initiation may be one month later than early nesting mallard or pintail. Most nests are located on upland areas less than 100 yards from water. Females place nests on dikes in marshes, in fields, meadows, and especially on well-vegetated islands. Gadwalls prefer tall dense cover similar to mallards, but often select sites with higher densities of broad-leaved plant species like stinging nettle. Nest placement, strong philopatric tendencies among successfully nesting females, and late nesting are some of the factors creating relatively high nest success in this species. Late nest initiation also make gadwall less prone to nest parasitism by redheads. Although gadwalls nest in the same prairie regions as pintails, mallards, and blue-winged teals, populations have been effected less by habitat changes because of their preference for semipermanent wetlands during breeding.

### Food Habits

Plant foods comprise 90-95% of an adult gadwalls diet during fall and winter. Unlike many vegetarian dabblers, gadwalls prefer succulent stems and leaves over seeds. Gadwalls feed on underwater aquatic plants such as pondweeds, naiads, wigeon grass, musk grass, algae, and coontail as well as emergents like spike rush and salt grass. They rarely graze on upland grass like American wigeon or frequent upland grain fields like mallards. Like other dabblers, female gadwalls increase their

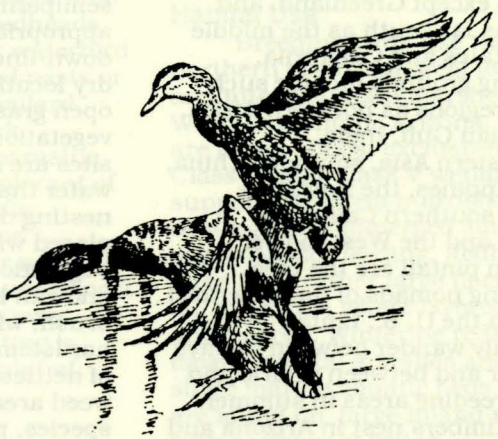
invertebrate consumption during spring and summer.

### Habitat Use

Because of their preference for aquatic vegetation, gadwalls frequent semipermanent or shallow permanent wetlands that support extensive submerged aquatic growth. Studies show that gadwalls most often loaf on more open water rather than on shoreline. Females lead broods from upland nest areas to deep water marshes or margins of impoundments to feed. Because gadwall nest late, some females are still flightless during late September or early October. These females may be subject to hunting pressure before they can fly.

## MALLARD

*Anas platyrhynchos*



### Distribution

Mallards are the most abundant and widely distributed duck in the Northern Hemisphere. Their extensive breeding range includes northern Alaska stretching northwest to the Bering Sea, eastward to the western shores of Hudson Bay, and south to California, New Mexico, Missouri, and Virginia. Their preferred breeding areas are in the southern regions of Saskatchewan, Alberta, and Manitoba. In Arizona, mallards are the most common breeding duck in the White Mountains. Significant numbers also occur in the wetlands on Anderson Mesa southeast of Flagstaff. Lesser numbers occur throughout the state whereever water is available. Mallards are among the earliest arrivals in spring and begin nesting early. Mallards are late fall migrants, typically moving south in advance of severe cold weather. Peak numbers reach Arizona in late October-early November and stay until freeze up. Mallards winter throughout most of the United States south to northern Mexico. Large concentrations occur in the Lower Mississippi Valley states of Arkansas, Mississippi, and Louisiana; the Central Valley of California, and the Central High Plains. The adaptability of mallards to feed on waste grain in fields and stock yards has resulted in significant numbers of birds wintering in otherwise unsuitable habitats like the intermountain valley's of the West and Northern Plains habitats.

### Nesting

The diverse breeding habits of the mallard range from subtropical marshes to arctic tundra. Mallards are very adaptable in their selection of nest sites. They may nest on muskrat or beaver lodges, man-made structures, in stumps or tree crotches, and at times over-water. Open country is generally preferred to forested areas. Nests are usually on uplands in dense vegetation. Mallards are usually the earliest breeding waterfowl in a region, nest initiation in Arizona montane habitats begins as early as mid April and lasts to early June. Thus, extensive residual vegetation is important to females. Brood habitats must be closely associated with resting sites and provide secure loafing areas with robust vegetation. Macroinvertebrates for developing ducklings are an important feature in brood habitats.

### Food Habits

Mallards are omnivorous and readily consume seeds of native and domestic crops as well as invertebrates. In North America, populations of mallards are basically daytime foragers that feed predominantly on plant material. Common foods consumed include seeds of watergrass, beaked sedge, manna grass, pondweeds, spike rush, and bulrush. They also feed on plant parts including pondweeds and musk grass. Where they are available, rice and corn are commonly used in winter. During molt and before egg laying, mallards increase their consumption of invertebrates that provide an important source of protein for egg synthesis and feather growth.

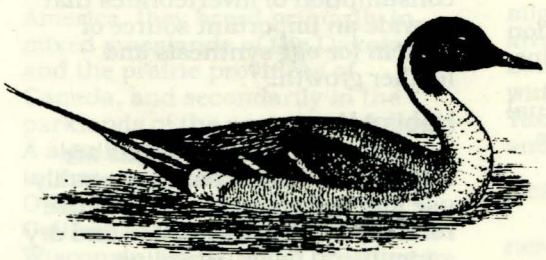
### Habitat Use

Many different habitats are attractive to mallards. They readily use forested riparian areas, dense robust emergent vegetation and dry agricultural fields. Breeding habitats commonly include shallowly flooded temporary or seasonal wetlands that serve as foraging and loafing areas combined with suitable nesting and brood cover. Beaver ponds are also a favorite habitat for pairs. Molting birds use marshes with large stands of robust emergent species like bulrush that provide good cover. In the most highly modified situations, wintering mallards will roost on reservoirs during the day and fly to nearby agricultural fields or cattle feed lots to feed during early morning and late afternoon.

## NORTHERN PINTAIL
*Anas acuta*

### Distribution

"The single race of pintail that inhabits the Northern Hemisphere ranges farther over the earth's surface than any other species of waterfowl" (Bellrose 1976). They nest in all arctic and subarctic habitats except Greenland, and extend as far south as the middle plains states and California. Wintering grounds include such diverse regions as northern Africa, the Persian Gulf, India, southeastern Asia, southern China, the Philippines, the Hawaiian Islands, southern California, Panama and the West Indies. Northern pintail are the true wandering nomads of the waterfowl world. In the U. S., Pintail commonly wander between flyways in winter and between prairie and arctic breeding areas in summer. Small numbers nest in Arizona and anywhere from 10,000-20,000 may stopover in October on their way to wintering grounds in southern Arizona, Mexico, Southern California or coastal Texas.



### Nesting

Breeding pintails are most commonly found in habitats that provide open vistas containing shallow marshes, quiet rivers, or shallow lakes. In Arizona, pintail will nest around seasonal and semipermanent wetlands with appropriate nesting cover. Nests are down-lined scrapes that occur in dry locations on bare ground, or in open grass or marsh areas where vegetation is low or sparse. Nest sites are located farther away from water than any other ground-nesting duck, but most often are placed within 100 yards of water. Vegetation at the site is variable, and can include spike rush, rabbit brush, wheat grass, willow, hardstem bulrushes, weedy patches of nettles and mustard, and burned weed areas. More often than other species, pintails will nest in farmland habitats such as hayfields, pastures, fallow fields, and field edges. These habitats makes their nests especially vulnerable to farming operations. Because pintails nest early and in open areas frequently having almost no concealment, they also suffer greater nest losses from predation. Renesting potential varies with the availability of water bodies.

### Food Habits

Pintails prefer to forage in waters they can reach by upending. Summer and fall foods are predominantly vegetative. Native plant foods include alkali and hardstem bulrush seeds, sago and horned pondweeds, smartweeds, salt grass, millets, sedges, nutgrasses, fall panicum, burreed, and musk grass. Pintails often do considerable crop damage during foraging by trampling cereal grains, especially barley and rice. During prelaying and laying, females commonly consume invertebrates that include insects, especially chironomid larvae and pupae, Cladocera, and clams obtained from shallow and seasonally wet habitats. Laying females consume more animal matter than nonbreeding or postlaying females.

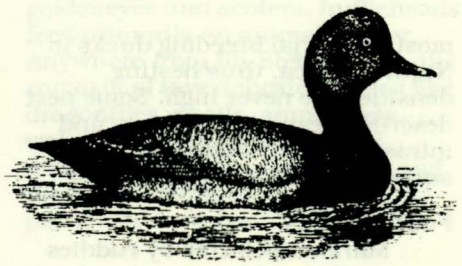
### Habitat Use

Pintails have a strong tendency for pioneering new areas, especially when traditional nesting habitat conditions deteriorate. They breed in mixed and shortgrass prairies, parklands, marshes and meadows of boreal forests, and subarctic deltas. Ponds with dense, low vegetational growth are favored as are areas with brushy thickets. In early spring, flocks of birds concentrate on newly thawed wetlands adjacent to larger ice-covered ponds and lakes. Pairs fan out from these sheet water areas that are available upon arrival and take up residence on potholes and other small water bodies. Females lead their broods farther overland from nest sites to brood habitat than other prairie ducks, and frequently move their broods from one pond to another. They rarely occupy a pothole for more than 14 days. During winter, pintails often concentrate in coastal habitats with shallow fresh or brackish water.

## REDHEAD
*Aythya americana*

### Distribution

Like cinnamon teal, redheads breed exclusively in North America. Canada's parklands provide the most extensive favorable habitat for breeding redheads, however the greatest densities occur in the marshes surrounding the Great Salt Lake. Other important breeding grounds occur in Washington, Oregon, Nevada, Idaho, Wyoming, western Montana, New Mexico, Colorado, North Dakota, Nebraska, Minnesota, Wisconsin and British Columbia. The redhead and ruddy duck are the two most common nesting divers in Arizona. As many as 40,000 birds may use Arizona wetlands during fall in route to wintering areas in coastal Mexico.



Redheads winter almost exclusively in coastal habitats, 80% occurring along the Gulf of Mexico. The 1,000 or so redheads that winter in Arizona are primarily in Lower Colorado River wetlands.

### Nesting

Preferred breeding habitat commonly includes non-forested environments with water areas that are sufficiently deep to provide permanent emergent vegetation. Redheads often appear on a wetland well in advance of nesting. Most nest sites are near or over shallow water that is usually somewhat alkaline and in dense stands of plants, although some nests are on islands, muskrat houses, or dry land. Redheads demonstrate a strong preference for hardstem bulrush beds over other vegetative cover types, with cattails and sedges as second and third choices. In Arizona, nest initiation ranges from early May to early July. Redheads regularly lay eggs in other waterbird nests, either other redhead nests or those of cinnamon teal, mallard, ruddy duck, or canvasback. Probably because of this parasitic habit, redhead pairs are tolerant of other breeders. Intraspecific parasitism may cause some redheads to abandon their nests. Desertion was the only cause of nest failure in one study on Arizona montane wetlands. Renesting is limited because of their habit of nesting late in the season.

### Food Habits

Redheads dive to grub in the bottom mud of shallow waters, feeding more extensively on aquatic plants (ca. 90%), especially during migration and in winter, and less on animal life than other diving ducks. They consume seeds, tubers, and leaves of pondweeds, wigeon grass, naiads, musk grass, algae, and bulrush. Animal species recorded in the diet include caddis flies, midges, water fleas, and pond snails.

### Habitat Use

Breeding birds use the northern prairies, boreal forests, and intermountain marshes of the West. In montane Arizona, redheads are found almost exclusively on Class IV and Class V wetlands that support hardstem bulrush for nesting and submerged aquatic vegetation for feeding. Redheads often form rather large flocks during fall migration where favored foraging areas occur. Wintering redheads use mostly coastal marshes and off-shore marine aquatic beds. Some are found on large inland marshes with permanent water.

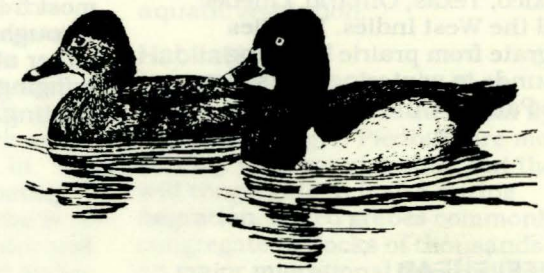
## RING-NECKED DUCK
*Aythya collaris*

### Distribution

The primary breeding range of the ring-necked duck encompasses the closed boreal forests of Canada, north and east of prairie breeding areas. In the United States, the largest breeding numbers occur in the Great Lake states, small numbers also nest in the montane regions of the western states. Small numbers of ringnecks breed in the White Mountains of Arizona. Greater than 90% of all wintering ringnecks occur in the eastern half of the continent, primarily along the Atlantic coast. Some ringnecks winter along the lower Colorado River.

### Nesting

Ringnecks nest in marshes, favoring those sedge meadow marshes at least partially surrounded by wooded vegetation, or in northern swamps and bogs with waters ranging from fresh to somewhat acidic. In Arizona, ringnecks prefer Class IV and V wetlands. Nests found in the White Mountains were located almost exclusively on floating islands of senesced and growing beaked sedge. If dry brooding sites are unavailable near the nest, females may brood the young on the nest. Ringnecks are much more prevalent on montane wetlands during migration when they are one of the dominant species.



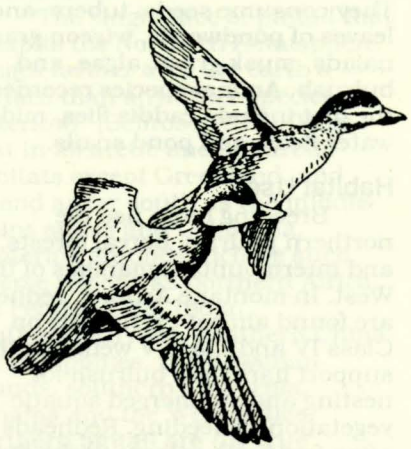
### Food Habits

Ringnecks feed in shallower waters than most diving ducks, usually as shallow as 1 foot but not more than 6 feet deep. Fall and winter foods include seeds of pondweeds, sedges, smartweeds, bulrushes, spike rushes, burreeds, the leafy structures of pondweeds and milfoil, and tubers of pondweeds. Animal matter consumed includes midge and mayfly larvae, waterboatmen, and snails.

### Habitat Use

Ringnecks like marshes, wooded ponds, bottomland lakes, mud- bottomed reservoirs, estuarine bays, and coastal lagoons. Because of modest home range requirements and little aggression between pairs, ringnecks are able to nest in higher densities than other ducks.

## RUDDY DUCK
*Oxyura jamaicensis rubida*



### Distribution

The ruddy duck is the only member of the stifftail group in North America. Breeding activities are centered on northern prairies, especially in southwestern Manitoba and central British Columbia, along with the intermountain basins and valleys of the West. Small, scattered colonies also breed in California, Arizona, Mexico, Texas, Ontario, Quebec and the West Indies. Ruddies migrate from prairie breeding grounds to wintering areas along the Pacific, Gulf, and Atlantic coasts from British Columbia south to Guatemala, the vast majority occurring along the Pacific.

### Nesting

Ruddies prefer freshwater and alkaline permanent marshes and ponds with extensive areas of emergent vegetation, relatively stable water levels, and enough water for landings and take-offs. They select large and small marshes and potholes ranging from 1-4 acres in size. Water depth is more important than plant composition or structure for nest sites. Over-water nests are in emergent vegetation with water depths of 10-12 inches. Nest locations may be as far as 120 yards from open water and 72 yards within marsh vegetation. Ruddies select plants that are relatively dense and pliable enough to be bent down to form nest supports. These include hardstem bulrush, cattail, and juncus. Hardstem bulrush seems to be the most frequently used vegetation throughout it's range. Nests may be either attached to the bottom, hanging from vegetation, or floating. Ruddies are one of the most territorial breeding ducks in North America, thus nesting densities are never high. Some nest desertion results from inter- and intraspecific parasitism, but nest success is usually high.

### Food Habits

Marshes selected by ruddies are usually mud-bottomed and not very deep, providing ample foraging opportunities. Ruddies primarily consume vegetation including seeds, tubers, and leafy parts of pondweeds, bulrush seeds, sedges, wigeon grass, musk grass, wild celery, and coontail. The diet varies with age, season and location. If vegetation is scarce, ruddies readily eat animal matter. Breeding females consume large quantities of midge larvae, in addition to bivalves, amphipods, ostracods, snails and insects.

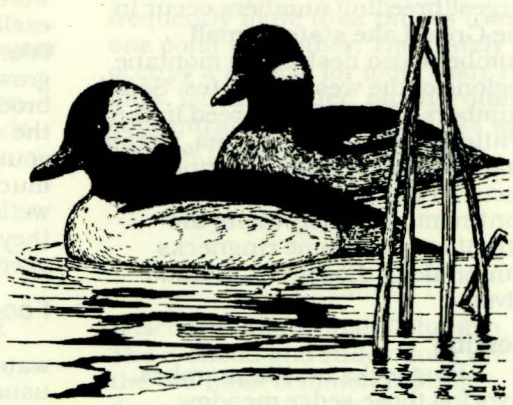
### Habitat Use

Superb divers, ruddies dive rather than fly to escape danger. They utilize mixed prairies and parklands with some use of the closed boreal forests, deltas, and intermountain freshwater marshes. In winter they primarily rely on brackish lagoons and shallow estuaries.

## BUFFLEHEAD
*Bucephala albeola*

### Distribution

The smallest breeding diving duck in North America, the bufflehead breeds in the closed boreal forest and prairie parkland region of Canada. The highest densities are found in British Columbia. Small numbers of bufflehead breed in Rocky, Sierra, and Cascade Mountain montane wetlands. Buffelheads do not breed in Arizona but are one of the most abundant species migrating through in the spring. Small numbers pass through Arizonal in fall, with up to several thousand wintering on Lower Colorado River wetlands. Primary winter ranges are the Pacific and Atlantic coasts from Alaska and Newfoundland to western Mexico and Florida respectively.



### Nesting

Bufflehead are cavity nesters. Their small size allows them to utilize unmodified cavitites excavated by flickers.

### Food Habits

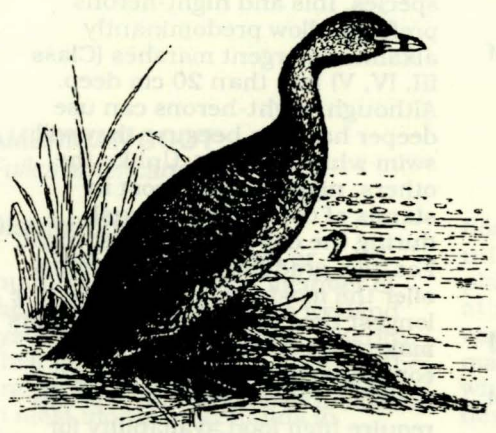
Like their close relatives the goldeneyes and scoters, buffleheads feed primarily on animal matter. Anywhere from 65-85% of their diet consists of invertebrate species like dragonflies, snails, amphipods, water boatmen, mayflies, and midges taken from the bottom and the water column. Snails in particular have been found to be important for birds wintering on freshwater habitats. Seeds of bulrush and leaves of pondweeds, musk grass and wigeon grass are also taken.

### Habitat Use

During summer, buffleheads prefer wetlands at least partially surrounded by trees containing potential cavities. During migration, large lakes and rivers are used frequently. Wintering birds prefer coastal lagoons and estuaries, or large freshwater lakes and rivers. In montane Arizona, buffleheads use the larger semipermanent and permanent wetlands that provide good invertebrate food resources.

## GREBES

Eared grebe *(Podiceps nigricollis)*
Pied-billed grebe *(Podilymbus podiceps)*



### Distribution

Pied-billed grebes breed throughout the United States, Mexico and most of the southern Canadian provinces. Wintering habitat includes large portions of their summer range, excluding the central plains states and provinces. Eared grebes are circumpolar in their distribution. In the U.S. they breed primarily west of a line stretching south from Minnesota through Missouri to the Gulf of Mexico. They winter along the Pacific and Gulf coasts and southern freshwater marshes in the U.S. and Mexico. Both species are common nesters on semipermanent and permanent wetlands in montane Arizona.

### Nesting

Both sexes of pied-billed grebes build the nest, which is usually well concealed in emergent vegetation like bulrush. The overwater nests are usually attached to surrounding vegetation in as much as several feet of water. In contrast, the poorly built floating nests of the female eared grebe is usually placed in shallow water and often in open habitats. Eared grebes may nest singly or in colonies. Young of both species frequently ride on the backs of their parents who feed them for the first few weeks of life.

### Food Habits

Both species are excellent divers, but they rarely dive greater than 20 feet deep or for periods longer than 30 seconds when feeding undisturbed. Aquatic insects and their larvae are the main diet of eared grebes. Common species include damselflies, mayflies, water boatmen, and midges but some small fish and crustacea are taken. The diet of pied-billed grebes includes many of the same insect species consumed by eared grebes in addition they commonly consume small fish, crayfishes, snails, and some aquatic vegetation.

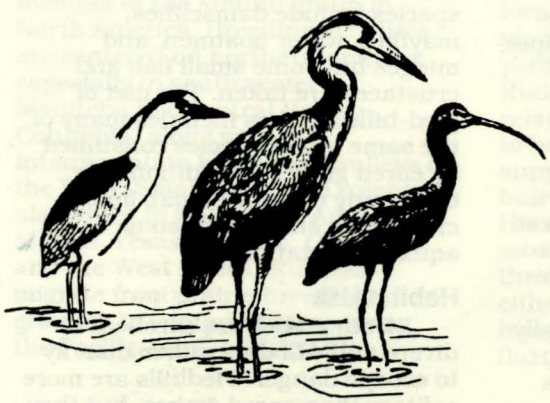
### Habitat Use

Both grebes are excellent divers and will dive rather than fly to escape danger. Piedbills are more solitary than eared grebes, but they will congregate in flocks during migration. Eared grebes commonly congregate in flocks of thousands on major migrational areas which are often alkaline lakes (e.g., Great Salt Lake, Salton Sea and Mono Lake). They require semipermanent and permanent wetlands with good emergent cover for nesting. Both species commonly use large reed marshes on the prairies. Because they need a running start to get airborne, sufficient open water must be available.

## WADERS
Great-blue heron *(Ardea herodias)*
Black-crowned night-heron *(Nyticorax nyticorax)*
White-faced ibis *(Plegadis chihi)*

### Distribution

Great-blue herons occur throughout the continental United States in summer and the southern half during winter. They breed in Arizona wetlands and may winter at lower elevations where open water remains. Black-crowned night-herons summer throughout the continental United States and winter predominantly on southern marshes and coastal lagoons and estuaries. White-faced ibis summer in the Great Basin, prairie plains states and coastal Texas, with concentrations in Utah and Texas.



Wintering areas are predominantly south of the U.S. in coastal Mexican marshes. Their presence in Arizona is restricted to spring and fall migration.

### Nesting

All three species may nest colonially in stands of cattail and bulrush. They may occur in single or mixed species colonies. Nests are constucted of sticks, twigs, and dead emergent vegetation. Great-blues and night-herons also commonly nest in many species of trees.

### Food Habits

Ibis forage on a variety of invertebrates including large crustacea (crayfish), insects, earthworms and snails. In montane wetlands snails appear to be the major food source. Night-herons stand motionless and capture fish with their bill. Fish are their primary food source but they also eat frogs, tadpoles, salamanders, dragonflies, and even algae and succulent plants. Great-blues eat almost any prey they can swallow; when present fish are the primary foods but great-blue herons also eat frogs, salamanders, snakes, rats, mice, rails, phalaropes, gophers, shrews and other young birds.

### Habitat Use

All species occupy shallow marsh habitats like those in northern Arizona. Great-blues commonly use a wide range of habitats including rivers, marshes, beaver ponds, lakeshores, ditches, and fields. Their longer legs and larger size allow them to occupy deeper habitats than the other species. Ibis and night-herons prefer shallow predominantly alkaline emergent marshes (Class III, IV, V) less than 20 cm deep. Although, night-herons can use deeper habitats because they will swim while foraging. Unlike the others, night-herons roost in stands of cattail and bulrush during the day and forage at night. For Ibis, gradually sloping basins offer the most feeding area over the longest time periods. Such habitats make invertebrate prey continuously available during natural drawdowns. Most species require high food availability for successful nesting.

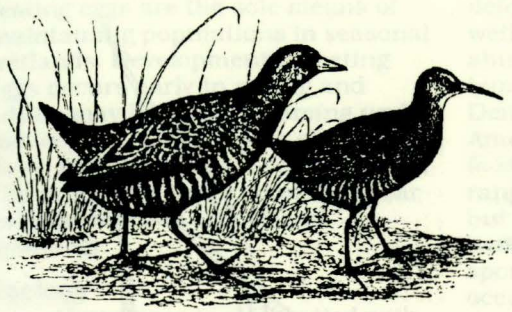
## SORA *(Porzana carolina)*
## VIRGINIA RAIL *(Rallus limicola)*

### Distribution

Both species are common breeders throughout much of North America. Sora's extend northward to the northern boundary of the southern Canadian provinces, east to Newfoundland and south across a line from Maryland, through northern Missouri to southern California. Virginia rails occupy the same areas in the United States but breed less extensively in Canada, primarily being restricted to parts of Alberta, Saskatchewan and Manitoba. Both species are common breeders in Arizona montane wetlands. Wintering ranges include the southern half of both coasts south to Central and South America. In addition, both species occupy inland habitats in Texas, Louisiana, California, Arizona and Florida.

### Nesting

Both species build there nests in emergents like bulrush, cattail, and sedges. Sora's typically select sites in deeper water than Virginia's and build more substantial nests that are either anchored to the bottom or suspended from the surrounding vegetation. Nests of Sora's may be quite high above the water level depending on flooding conditions. Virginia rails may construct an over hanging canopy of vegetation for additional protection and concealment. Young are precocial and follow the female around the marsh in search of food soon after hatch.



### Food Habits

Virginia rails are primarily carnivores eating snails, tadpoles, slugs, small fish and earthworms. Soras are more omnivorous. In migration, Soras prefer the seeds of smartweeds, millet, bulrush and wild rice; they also eat a variety of leafy vegetation. Young chicks follow their parents through the marsh eating small insects, crustacea, and some seeds and vegetation.

### Habitat Use:

Unlike their easily seen relative the coot, both rail species are secretive, primarily staying in dense emergent cover. Presence is often confirmed by voice rather than sight, and high numbers of birds can occupy seemingly "empty" habitat. Their preference for robust emergent cover in summer limits them to seasonal, semipermanent and permanent wetlands in Arizona. Shallow wetlands with good cover and maximum edge habitat between different vegetation zones and vegetation-open marsh-mudflats provide the best foraging opportunities for broods and migrating birds. These conditions are created naturally by a diverse basin topography and dynamic flooding regimes. During fall migration both species prefer low areas of flooded annual grasses and other seed producing annuals. During spring perennial habitats are used more because they usually provide the dense cover these species prefer. Any practices that reduce robust residual emergent vegetation will probably reduce spring migration populations and nesting densities.

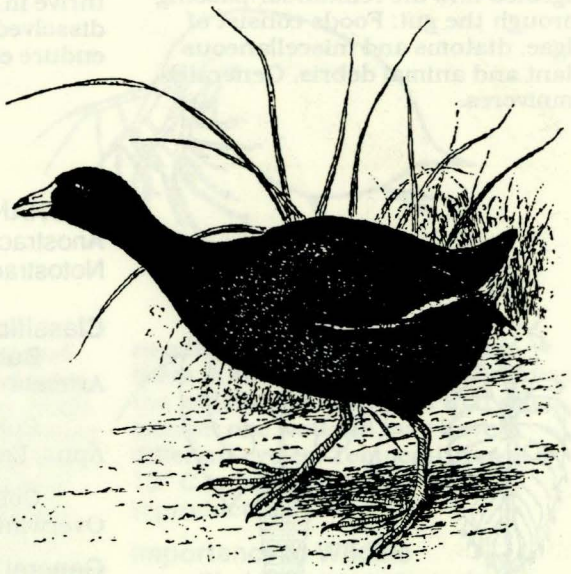
## AMERICAN COOT
*Fulica americana*

### Distribution

The American coot, or mudhen, is the largest member of the Rallidae and occupies wetland systems throughout North America. Their greatest densities occur in the prairie pothole region. Coots breed in most montane wetlands in Arizona with suitable nesting habitat. During migration coots move in a broad front using most water areas throughout the United States. It is during these times when there peculiar behavior of congregating into tight flocks (as many as 100 birds) on the water can often be seen. Large concentrations of wintering coots are found in the coastal marshes of Louisiana and Texas, the Central Valley of California, and the wetlands of Florida. Small numbers of coots winter along the Lower Colorado River marshes in Arizona.

### Nesting

Coots are highly territorial during breeding. They court and mate on specially built platforms that are made of marsh plants and are near the water surface. Coots nest over water, where they build floating platforms or utilize muskrat-feeding platforms. Nests are attached to emergent vegetation and nest materials usually include whatever surrounds the nest sites. Nest success is normally high. Nest failure results mainly from severe wind or wave action, and from fluctuating water levels.



### Food Habits

Although young birds are fed invertebrates for the first few weeks of life, coots primarily are vegetarians. Important foods include pondweeds, sedges, algae, and grasses, although some forage crops are also consumed. In winter, coots regularly graze pastures, golf courses and lawns.

### Habitat Use

Although very adaptable, coots usually restrict breeding to freshwater habitats with the highest nesting densities occurring in marshes with good interspersion between open water and robust emergent vegetation such as bulrush and cattail. They commonly use lakes, tideflats, marshes, wet grasslands, and fields. During migration, coots concentrate on rivers, lakes, ponds, reservoirs, and sewage lagoons. Natural brackish and freshwater wetlands are most important for wintering coots although other habitats are used.

# Appendix 5

## Common Invertebrates Of Montane Wetlands In Arizona

### OLIGOCHAETES
*(Aquatic earthworms)*

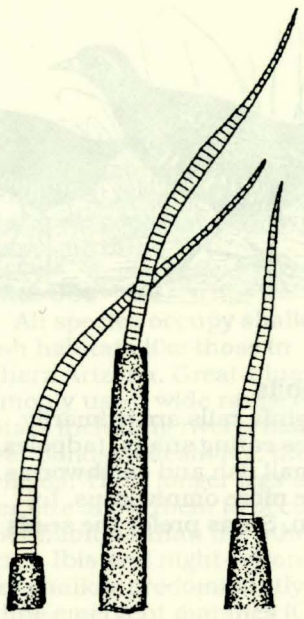
#### Classification
Oligochaeta-Lumbricidae; Collector-gatherer; Overwintering resident.

#### General Description
Unlike terrestrial worms, aquatic worms are smaller and more delicately constructed. Size ranges from 0.04-1.2 inches. The body is thin and internal organs can be seen easily in living organisms. Number of segments range from 7-500 depending on the species. Hair-like structures (setae) occur on all but the first segment; number, arrangement and type of setae are important in species identification.

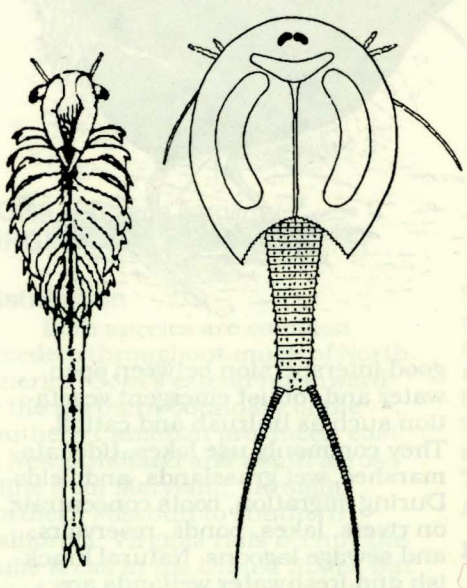
#### Feeding Habits
Bottom substrates are ingested during feeding, with the organic portion being retained and digested and the remaindar passing through the gut. Foods consist of algae, diatoms and miscellaneous plant and animal debris. Generally omnivores.

#### Life History
Reproduction in aquatic worms is either by budding (asexual) or by syngamic reproduction typical of terrestrial earthworms. Cocoons containing embryo are deposited in vegetation and debris. Life cycle takes 1-2 years. The capacity to regenerate lost or damaged segments varies within the group.

#### Ecology
Locomotion on substrates is a crawling movement, involving contractions of the muscular body wall. Aquatic worms mix bottom mud and debris much like terrestrial worms mix soil. Temperature not usually limiting, but often determine the abundance of worms. Some forms encyst in hardened cases of mucus when water is 43°F or lower. Most species thrive in low concentrations of dissolved oxygen; some species can endure extended anoxic periods.



#### Importance to Wildlife
Oligochaetes are often eaten by waterfowl. Oligochaetes serve as an important nutrient link between detrital resources and waterfowl.



### EUBRANCHIOPODA
Anostraca (Fairy shrimp)
Notostraca (Tadpole shrimp)

#### Classification
Eubranchiopoda-Anostraca-Artemia

Eubranchiopoda-Notostraca-Apus, Lepidurus

Collector-filter, Scavengers; Overwintering residents.

#### General Description
Species range from 3-100 mm long. Fairy shrimp have 20 body segments, 11 pairs of swimming legs, no carapace, and well separated stalked eyes. Tadpole shrimp have from 35-70 pairs of legs, sessile and closely spaced eyes, and a carapace that gives them the look of small horseshoe crabs. Coloration varies from white, green, blue to orange. Fairy shrimp hold their eggs in a sack, whereas the last leg of tadpole shrimp is specialized to carry eggs.

#### Food Habits
Both groups nonselectively filter detritus, algae, rotifers and protozoa with the aid of leg movements. However, Tadpole shrimp have been observed feeding on dead tadpoles, earthworms and frog eggs. Fairy shrimp frequently feed along the bottom.

#### Life History
Reproduction is parthenogenic most of the year. Females produce summer, or thin shelled eggs, and winter, or thick shelled eggs. Winter eggs, also called resting eggs can withstand extensive periods of drying and freezing. Laboratory experiments have shown eggs to remain viable in temperature

# Appendix 5

## Common Invertebrates Of Montane Wetlands In Arizona

### OLIGOCHAETES
*(Aquatic earthworms)*

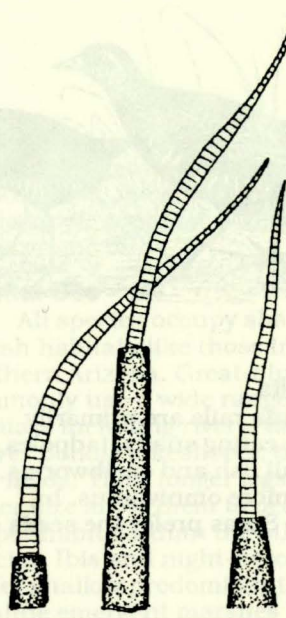
#### Classification
Oligochaeta-Lumbricidae; Collector-gatherer; Overwintering resident.

#### General Description
Unlike terrestrial worms, aquatic worms are smaller and more delicately constructed. Size ranges from 0.04-1.2 inches. The body is thin and internal organs can be seen easily in living organisms. Number of segments range from 7-500 depending on the species. Hair-like structures (setae) occur on all but the first segment; number, arrangement and type of setae are important in species identification.

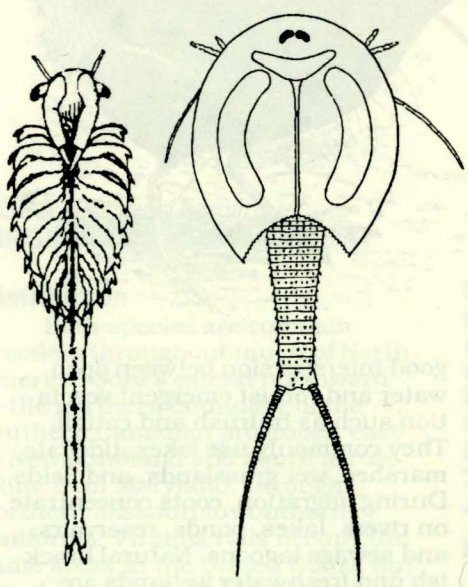
#### Feeding Habits
Bottom substrates are ingested during feeding, with the organic portion being retained and digested and the remaindar passing through the gut. Foods consist of algae, diatoms and miscellaneous plant and animal debris. Generally omnivores.

#### Life History
Reproduction in aquatic worms is either by budding (asexual) or by syngamic reproduction typical of terrestrial earthworms. Cocoons containing embryo are deposited in vegetation and debris. Life cycle takes 1-2 years. The capacity to regenerate lost or damaged segments varies within the group.

#### Ecology
Locomotion on substrates is a crawling movement, involving contractions of the muscular body wall. Aquatic worms mix bottom mud and debris much like terrestrial worms mix soil. Temperature not usually limiting, but often determine the abundance of worms. Some forms encyst in hardened cases of mucus when water is 43°F or lower. Most species thrive in low concentrations of dissolved oxygen; some species can endure extended anoxic periods.



#### Importance to Wildlife
Oligochaetes are often eaten by waterfowl. Oligochaetes serve as an important nutrient link between detrital resources and waterfowl.



### EUBRANCHIOPODA
Anostraca (Fairy shrimp)
Notostraca (Tadpole shrimp)

#### Classification
Eubranchiopoda-Anostraca-Artemia

Eubranchiopoda-Notostraca-Apus, Lepidurus

Collector-filter, Scavengers; Overwintering residents.

#### General Description
Species range from 3-100 mm long. Fairy shrimp have 20 body segments, 11 pairs of swimming legs, no carapace, and well separated stalked eyes. Tadpole shrimp have from 35-70 pairs of legs, sessile and closely spaced eyes, and a carapace that gives them the look of small horseshoe crabs. Coloration varies from white, green, blue to orange. Fairy shrimp hold their eggs in a sack, whereas the last leg of tadpole shrimp is specialized to carry eggs.

#### Food Habits
Both groups nonselectively filter detritus, algae, rotifers and protozoa with the aid of leg movements. However, Tadpole shrimp have been observed feeding on dead tadpoles, earthworms and frog eggs. Fairy shrimp frequently feed along the bottom.

#### Life History
Reproduction is parthenogenic most of the year. Females produce summer, or thin shelled eggs, and winter, or thick shelled eggs. Winter eggs, also called resting eggs can withstand extensive periods of drying and freezing. Laboratory experiments have shown eggs to remain viable in temperature

ranges from -190° to 81° C. These resting eggs are the sole means of maintaining populations in seasonal wetlands. Development of resting eggs occurs early in spring and adults may be seen swimming under the ice. Life cycles are as short as 15 days, but as long as several months. The number of generations per year usually depends on wetland hydrology.

### Ecology

Abundance is closely tied with temperatures, 4-13° C is optimal. Eubranchs are essentially defenseless, thus rarily occur in wetlands with fish. They reach peak abundance in shallow ephemeral, temporary, and seasonal wetlands. Densities can be so great that native Americans once utilized them for food. Mature individuals tolerate a range of salinity and pH conditions but prefer slightly alkaline, thus basic, habitats. Distribution is sporadic. High populations may occur in one year but not the next, or in one wetland but not similar nearby wetlands. Rarily does more than one genus occur in a wetland.

### Importance to Wildlife

Fairy shrimp are important foods for early breeding waterfowl like pintail and mallard as well as for later breeders like shovelers, gadwall, and teal. They are also used by feeding phalaropes and avocets. They are also preyed upon by odonates, predaceous beetles, and amphibians.

## CLADOCERA
*(Water fleas)*

### Classification

Crustacea-Cladocera-Daphnia; Collector-filter; Overwintering spring recruits.

### General Description

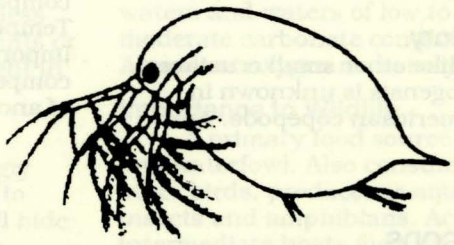
Species range from 0.2-3.0 mm long. The abdomen and thorax are covered by a carapace that has a bivalve appearance. The body is not clearly segmented, second antennae are large, reinforced and attached to strong muscles. Colors range from light to transluscent in limnetic species to yellow-brown, red-brown and almost black in littoral species.

### Feeding Habits

Constant motion of the thoracic legs produces a current between the halves of the carapace. Food is filtered out and passed to the mouth where it is broken down by the mandibles. Common food includes algae, detritus, and protozoa.

### Life History

Reproduction is mostly parthenogenic, but males can be seasonally abundant in spring and fall. Young hatch as miniature adults. The sex of the egg seems to be in part dependent on food availabilty and temperature. Females produce parthenogenic eggs that hatch shortly after being laid and sexual eggs that are protected in a thickened, hardened casing called an ephippium. These ephippia withstand drying and freezing and hatch upon reflooding. Sexual eggs and ephippia are produced in much lower numbers by species inhabiting permanently flooded wetlands. Life cycles take from 4 to 5 weeks and consist of egg, juvenile, adolescent, and adult phases.



### Ecology

Cladocera occur mostly in freshwater, are eurythermal, and can tolerate low oxygen concentrations but not anoxia. Species occur from pH's of 6.5-8.5 and occupy benthic, littoral, and limnetic habitats. Abundances are usually seasonal but predicting them is virtually impossible because the wide range of species that often inhabit one wetland may have different cycles. Temperatures of 6-12° C is best for growth and reproduction.

### Importance to Wildlife

Cladocera are extremely important foods for nesting female northern shovelers, gadwalls and to a lesser extent mallards. Cladocera may make up 95% of certain fish diets. They also serve as prey for aquatic insects.

## COPEPODS

### Classification

Crustacae-Copepoda

Collector-filter, Grazer, Predator; Overwintering-spring recruits

### General Description

Species range in size from 0.3-3.2 mm long, most are under 2 mm. The three free-living suborders have segmented bodies, fused cephalothorax and a tapered abdomen. Paired swimming legs are located on the thorax. Most are drab grays and browns but some littoral and high altitude species are bright orange, purple and red.

### Feeding Habitats

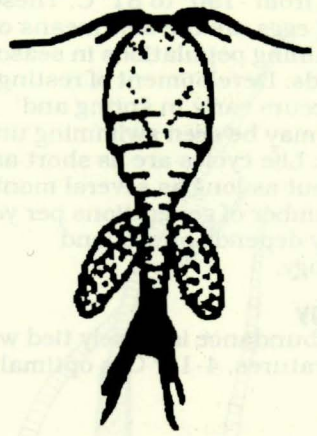
Copepods exhibit a wide range of feeding habits. Many filter algae, plankton, and detritus, others prey on protozoans or browse and scrape bacteria, fungi, and other detritus from substrate and plant surfaces.

### Life History

Unlike other small crustacea, parthenogensis is unknown in North Americaan copepods. An abundance of males can be found at all times. The timing of reproduction varies depending on the species and wetland hydrology. Females produce resting and summer eggs. Thick walled resting eggs survive freezing and drought conditions and allow copepods to inhabit seasonal wetlands. Eggs are carried in two sacks that are suspended laterally from the genital body segment. Eggs hatch and go through 6 nauplius stages, 5 copepodid stages to reach adult status. Life cycles can take anywhere from 7 days to 1 year.

### Ecology

Species move about by crawling on substrate or swimming with the aid of antennae and legs. Limnetic species reach densities of 1,000 individuals per liter. Limnetic species are small, have poorly developed appendages and are transluscent or white in color compared to littoral species. Temperature is thought to be an important determinator of species composition. Copepods are tolerant of anoxic conditons and adults may



form detrital covered mucosal cysts to help survive anoxic or dry periods.

### Importance to Wildlife

Some species are intermediate hosts for some tapeworms of waterfowl and some nematodes and flukes of birds. Copepods are an important intermediate step in food chains between algae, bacteria and protozoans and fish. Copepods have been recorded in the diet of gadwalls.

## OSTRACODS

*(Seed shrimp)*

### Classification

Crustacea-Ostracoda;

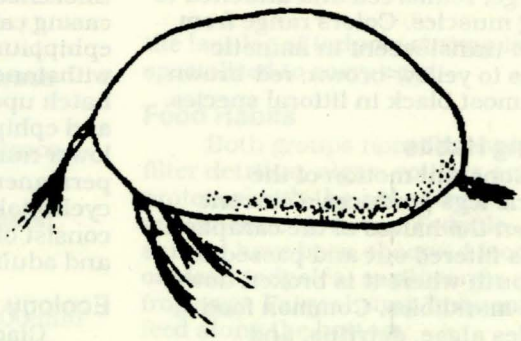
Omnivorous scavengers; Overwintering resident.

### General Description

North American seed shrimp reach 3 mm in length but most are less than 1 mm. They resemble miniature muscles, closing the halves of their shell with strong adductor muscles. They have no concentric growth lines like Conchostraca. The first set of antennae bear short stiff bristles for digging or long setae for swimming. The second pair of antennae are used for locomotion, but also for reproduction in males. Colors range from white, yellow, gray, red, brown, black, and green.

### Feeding Habitats

Food consists mostly of bacteria, molds, algae, and fine detritus. Although some scavenging on dead vertebrates has been observed, small food particles are channeled into the mouth by the setae and larger bits are gathered by the antennae and broken down by the mandibles.



### Life History

Ostracods exhibit both parthenogenic and sexual reproduction. In parthenogenic species males are rarely if ever found. Young are born as nauplia, and gain adult size and shape through a series of 8 instars. Females of most species are oviparous. Eggs can overwinter or aestivate during cold or drought conditions, eggs have remained viable for 20 years. Species usually have one cycle per year in seasonal wetlands, but 2-3 in more permanent waters.

### Ecology

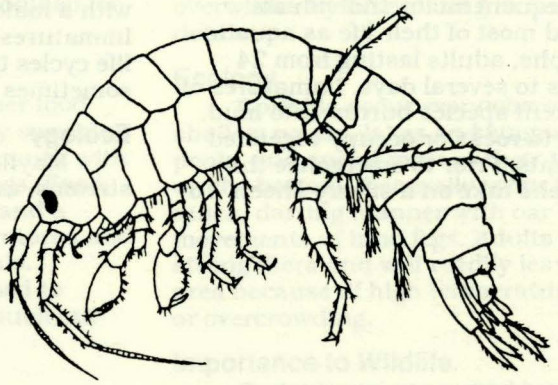
The nature of the substrate has little influence on the distribution or composition of seed shrimps. Individuals are found in mud, detritus, gravel, or on living plants. Likewise, species are rarely restricted to specific wetland types. The largest number of species is usually found on mud bottoms and prefer depths of less than 3 feet. They tolerate a wide range of temperature and oxygen conditions, and commonly occur in anoxic lake sediments. However, they will not occur in heavily polluted waters.

### Importance to Wildlife

Seed shrimp are not a major food for waterfowl, although they occur in the diets of laying females. Ostracods are intermediate hosts for some tapeworms of waterfowl.

## AMPHIPOD

*(Scud, sideswimmer)*



### Classification

Crustacea-Amphipoda-Crangonyx, Gammarus; Shredder; Overwintering resident.

### General Description:

Most species 0.2-0.8 inches long. Body is laterally compressed, resulting in sideways motion, hence the name sideswimmer. Eyes well developed and unstalked. Each thoracic segment has a pair of legs; first pair modified for grasping. Wide range of colors; light brown, greenish, blueish, purple, dark brown and reddish. When preserved usually white or cream colored.

### Feeding Habits

Voracious feeders on all kinds of plant and animal matter. Browse on film of microscopic plants, animals and organic detritus covering leaves, stems and other substrates. Omnivores, detritivores, general scavengers.

### Life History

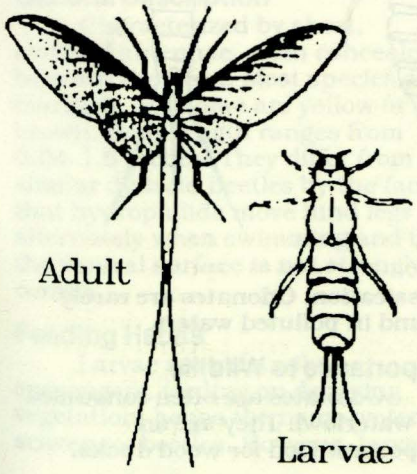
Direct development with newly hatched young with adult appendages. Growth in stages (instars); number of instars depends on species. Interval between molts (3-40 days) depends on food, temperature and species. Life cycle usually complete in a year or less (univoltine). Overwinter as adults or eggs or survive summer drought in leaf litter layers.

### Ecology

Cold stenotherms; strongly thigmotactic; react negatively to light. During daylight they will hide in vegetation or under organic debris. Skittering motion when moving on substrate or rapid undulating swimming above substrate. Restricted to shallow waters and waters of low to moderate carbonate content. Abundant oxygen necessary.

### Importance to Wildlife

A primary food source for fish and waterfowl. Also consumed by other birds, predaceous aquatic insects and amphibians. Act as intermediate hosts for a variety of parasites including tapeworms of waterfowl and fish. Serve as an important nutrient link between detrital resources and waterfowl.




## EPHEMEROPTERA

*(Mayflies)*

### Classification

Insecta-Ephemoptera-Ephemerella, Ephemera, Hexagenia. Browser

### General Description

Adults are small to medium-sized winged terrestrial insects Wings are held vertically when resting. Two or three long, segmented filaments extend from the posterior end of the long tapered abdomen. Nymphs show more morphological variation than adults, without caudal filaments they range in size from 3-28 mm long. They have elongated bodies, large head, well-developed mouths, stout legs, and paired tracheal gills which separate them from other aquatic insect nymphs. Colors range from dull brown, gray, blackish, green and reddish.

### Feeding Habits

Adult mayflies do not feed. Nymphs are almost exclusively herbivorous, browsing on the substrate, algae or higher aquatic plants, grinding up debris with their mandibles.

### Life History

Direct development, newly hatched nymphs develop additional gill and antennae segments with subsequent molts. Individuals spend most of their life as aquatic nymphs, adults lasting from 24 hours to several days. Immatures of different species burrow into mud, cling to rocks or occupy vegetated habitats. Prior to emergence the nymphs take on a silvery sheen. To emerge, nymphs usually rise to the surface although some crawl out on rocks or vegetation. Emerging mayflies are sexually immature subimagos, maturity is reached following an additional molt. On warm, still summer evenings the swarming adults can give the impression of fog over a wetland. These swarms consist mostly of males. Emerging females enter the swarm leaving almost immediately with a male that fertilizes her. Immatures are slow growing and life cycles typically take one year, sometimes 6 months.

### Ecology

Mayflies occur in lakes, streams, and ponds with an abundance of oxygen. Most occur in waters less than 15 feet deep. Water movement appears to be a major factor determining species composition in a wetland. Some species crawl about on their stout legs, others swim using their caudal filaments and gills. Nymph morphology largely depends on its habit of being either free-ranging, clinging, climbers, or burrowers.

### Importance to Wildlife

Both the nymphs and adults are an important food for wetland birds, fish and amphibians. Waterfowl will tip-up or dive for the nymphs and during large hatches both adult and ducklings feed on the emerging adults at the water surface.

## ODONATES

*(Dragonflies, damselflies)*

### Classification

Insecta-Odonata/Libellulidae, Lestidae-*Libellula, Lestes;* Predator; Overwintering summer recruits.

### General Description:

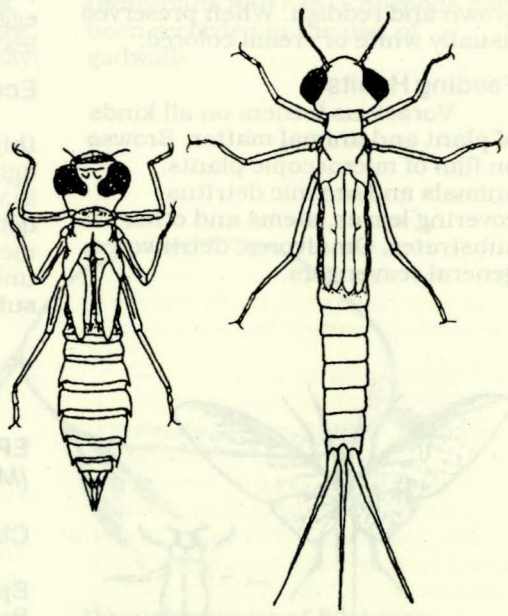
A wide range in body size occurs for nymphs: dragonflies, 0.5-1.75 inches; damselflies, 0.4-0.9 inches. These are robust or elongated insects, often appearing grotesque. Generally gray or green in color. Body can be smooth or rough, sometimes covered with algae. Damselflies are more slender than dragonflies. Damselflies also have three leaf-like gills at the tip of the abdomen.

### Feeding Habits

Although all odonates are carnivores, feeding habits and feeding mechanisms vary. Some actively seek and stalk prey, while others remain motionless until prey are near enough to strike. Food consists of other aquatic insects, annelids, small crustaceans, mollusks and larval fish.

### Life History

Incomplete metamorphosis, with egg, nymph and adult. Eggs can be scattered on water surface or deposited in masses in floating algal mats, sand, mud, aquatic plants, or moss near water's edge. Most species have 11 to 14 nymphal instars; length of each instar varies depending on species, temperature and food supply (3 days to 6 months). Life cycle usually lasts 1 year, but can vary from 6 months to 4 years. Nymphs undergo changes in size and body parts until emergence as adults.



### Ecology

Odonates climb vegetation, move slowly through organic debris or burrow into bottom substrates. They are found in lakes, ponds, streams and temporary waters. Some species are able to withstand long periods of dessication. Odonates are rarely found in polluted waters.

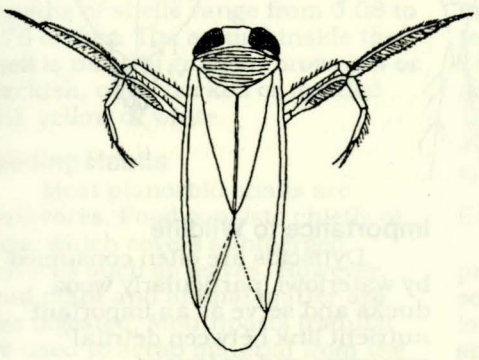
### Importance to Wildlife

Odonates are often consumed by waterfowl. They are an important food for wood ducks.

## CORIXIDS
*(Water boatmen)*

### Classification
Insecta-Hemiptera/Corixidae-*Sigara;* Collector-gatherer or Piercer-herbivore; Non-wintering spring recruit.

### General Description
Corixids are medium to small organisms, usually less than 0.5 inche long. Body is somewhat flattened above. Color is dark grayish, usually mottled or marked with yellow, brown or black. Hind legs are modified for swimming; long, flattened and fringed with hairs. Middle legs also long, but slender and not modified for swimming.



### Feeding Habits
Corixids gather food from the bottom by sweeping material into the mouth with their short front legs. Food consists of debris and a variety of algae, Protozoa and microscopic animals. Mouthparts are used to pierce tissue and suck out contents.

### Life History
Metamorphosis is incomplete. Eggs are attached to stems of aquatic plants. Typically 5 nymph stages occur. Corixids have 1, 2 or 3 generations per year depending on species, temperature and food conditions. Nymphs or adults overwinter by hibernating in mud or debris.

### Ecology
Corixids occur everywhere in shallow ponds, lakes and stagnant pools, and spend most of their time on the bottom. Generally swim in quick, darting manner with oar-like movements of hind legs. Adults are strong fliers and will readily leave an area because of high temperatures or overcrowding.

### Importance to Wildlife
Corixids are consumed by waterfowl.

## HYDROPHILID
*(Water scavenger beetle)*

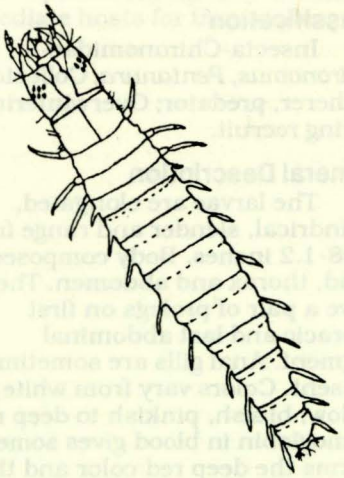
### Classification
Insecta-Coleoptera/Hydrophilidae-*Berosus, Tropisternus*; Collector-gatherer (larvae), Predator (adult); Non-wintering spring migrants.

### General Description
Characterized by short, clubbed antennae, often concealed beneath the head. Most species are blackish, but some are yellow or brown. Body length ranges from 0.04-1.6 inches. They differ from the similar dytiscid beetles by the fact that hydrophilids move hind legs alternately when swimming and that the ventral surface is not strongly convex.

### Feeding Habits
Larvae are primarily scavengers, feeding on decaying vegetation; hence the name water scavenger beetles. However, larvae also consume algae and other living plant material. The adults are predators, primarily on other aquatic insects.

### Life History
Complete metamorphosis. Some species deposit eggs that remain uncovered, but most species enclose eggs in cases or cocoons. Larvae have 3 instars. Pupal stage usually lasts less than 3 weeks. Usually the adult overwinters. Usually 1 generation a year, but in some species there are 2 generations.

### Ecology
Hydrophilids are common in quiet, shallow pools or ponds. Some species are good swimmers, most crawl on vegetation and bottom substrates. Hydrophilids must return periodically to the surface to replenish their oxygen supply.



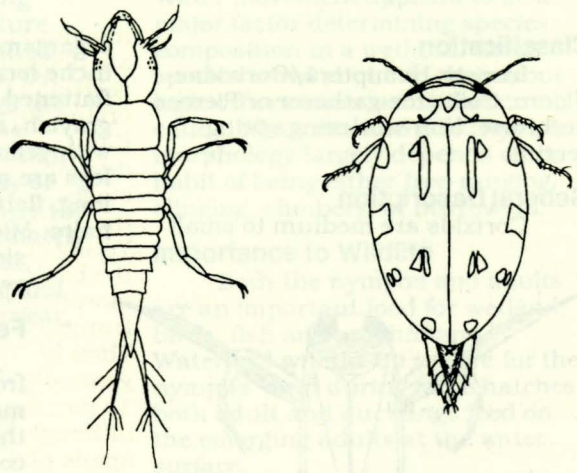
### Importance to Wildlife
Hydrophilids are consumed by waterfowl, particularly wood ducks and serve as an important link between detrital resources and waterfowl.

## DYTISCIDS
*(Predaceous diving beetles)*

### Classification
Insecta-Coleoptera/ Dytiscidae-*Agabus, Coptotomus;* Predator; Non- wintering spring recruits.

### General Description
Adults range in size from 0.04-1.6 inches. They are shiny black or brownish black, but often marked with dull yellow, green or bronze. Antennae are long and thread-like. Hind legs are adapted for swimming; legs are more or less flattened, elongated and hairy. Larvae are elongated and spindle shaped. The head is large and round, oval or elongated; mouthparts (mandibles) are sickle shaped.

### Feeding Habits
Adults and larvae are both carnivorous with voracious feeding habits. Food consists of many aquatic animals. Larvae lunge and clutch prey in sickle shaped mandibles, which are adapted for piercing and sucking.



### Life History
Life cycle generally completed in 1 year. Eggs deposited on litter or under objects or within living plant tissue. Either larvae or adults overwinter depending on when eggs hatch.

### Ecology
Most species are efficient and graceful swimmers. Dytiscids need a clean substrate and aquatic vegetation. Few species occur in muddy waters.

### Importance to Wildlife
Dytiscids are often consumed by waterfowl, particularly wood ducks and serve as an important nutrient link between detrital resources and waterfowl.

## CHIRONOMID
*(Midge, bloodworm)*

### Classification
Insecta-Chironomidae-*Chironomus, Pentanura;* Collector-gatherer, predator; Overwintering spring recruit.

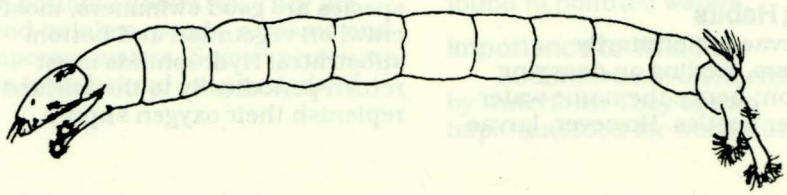
### General Description
The larvae are elongated, cylindrical, slender and range from 0.08-1.2 inches. Body composed of head, thorax and abdomen. They have a pair of prolegs on first thoracic and last abdominal segment. Anal gills are sometimes present. Colors vary from white, yellow, bluish, pinkish to deep red. Hemoglobin in blood gives some worms the deep red color and the common name of bloodworm.

### Feeding Habits
Chironomids are chiefly herbivores and feed on algae, higher aquatictic plants and organic debris. However, some species are predators, chiefly on oligochaetes and insect larvae.

### Life History
Chironomids have 4 distinct life states: egg, larvae, pupa and adult. Eggs are deposited singly, or in masses or strings on the surface, bottom or aquatic vegetation. Larval stage, with 4 instars, lasts from 2 weeks to 4 years depending on species, temperature and food conditions. Pupa remain hidden in debris until emergence takes place. Adults, which are aerial/terrestrial, are short-lived, do not feed and serve to reproduce and disperse. The adults are non-biting dipterans.

### Ecology
Chironomid larvae occur everywhere in aquatic vegetation and the bottom of all types of freshwater. May occur in great abundance (> 50,000/m2). Many species construct fragile tubes composed of algae, fine silt or sand grains cemeted together. Some species overwinter in larval hibernation cocoons. Chironomids can withstand poor water quality and very low oxygen levels.

### Importance to Wildlife
Chironomid larvae regularly are consumed by waterfowl and serve as an important nutrient link between detrital resources and waterfowl.



## PLANORBID SNAILS
*(Orb snails)*

### Classification

Gastropoda-Pulmonata-Planorbidae-Gyraulus, Promenetus; Physidae-Physae, Lymnaeidae-Lymnae, Scrapers; Overwintering residents.

### General Description

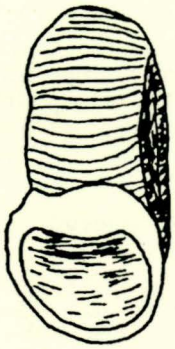
Snail shells are disk-like or orb-like or exhibit a low spiral. Lengths of shells range from 0.08 to 2.75 inches. The animal inside the shell is usually grayish, brownish or blackish, often flecked or mottled with yellow or white.

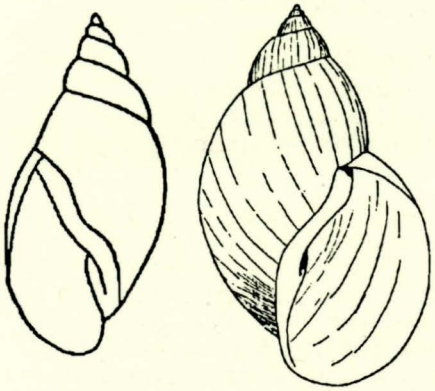
### Feeding Habits

Most planorbid snails are herbivores. Food consists chiefly of algae which covers submerged surfaces such as leaves. However, dead plant and animal matter are also digested. Mouthparts (radula) are used to scrap material from the surface. Physids and Lymnaeids commonly eat plant matter and are also good scavengers and essentially omnivorous.

### Life History

All three families are hermaphroditic-both male and female reproductive organs in same individual. Eggs are deposited in gelatinous masses on the substrate. Early developmental stages occur in the egg mass. Young snails have the basic morphological features of adults. Their life cycle generally lasts 9-15 months, although some species have life spans of 2-4 years.





### Ecology

Planorbid snails require the presence of adequate dissolved solids and calcium for shell formation. Fewer numbers of species occur in waters low in calcium carbonate. Low pH and dissolved oxygen also limit the number of species. Most require neutral to alkaline pH (7.0) and ample supplies of oxygen. Most species occur in water <10 feet deep. In wetlands that freeze to the bottom, snails commonly burrow into the mud, similarly they will aestivate during summer drought conditions in the wetland bottom. Species of Lymnae are capable of producing a thin sheet of mucus just within the shell aperture. Upon drying this film hardens providing an effective seal against dissection. This adaptation may be why Lymnaeids are prevalent in some seasonal wetlands while other taxa of snails are not.

### Importance to Wildlife

Planorbid snails are an important food source for fishes, waterfowl, shorebirds, waders and occasionally amphibians. Some species of planorbid snails serve as intermediate hosts for trematodes.

* U.S. GOVERNMENT PRINTING OFFICE 1993-0-774-223/84025